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ABSTRACT

The training manual is designed to help Navy personnel meet the occupational qualifications for advancement to Builder First Class and Chief Builder. The introductory chapter provides information to aid personnel in their preparation for advancement and outlines the scope of the Builder rating and the types of billets to which he can be assigned. The remainder of the volume discusses the following specific topics: supervision; planning, estimating, and scheduling; concrete construction; masonry construction; plastering, wall tiles, and acoustical ceilings; light frame construction; heavy construction; construction inspection for buildings and additional structures; and maintenance inspection. (Author/NH)

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BUILDER 1 & C

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NAVAL TRAINING COMMAND

RATE TRAINING MANUAL NAVTRA 10649-F

PREFACE

The primary purpose of training is to produce a combat Navy which can maintain control of the sea and guarantee victory. Victory at sea depends upon the state of readiness of "All Hands" to perform tasks assigned to them in accordance with the needs of the Navy. This Rate Training Manual provides information related to the tasks assigned to the First Class and Chief Builders who supervise the construction, maintenance, and repair of wooden, concrete, and masonry structures. It is only when personnel assigned to naval components can and do perform their tasks efficiently that each component will be operating at a high state of readiness and adding its contribution which is essential to guarantee victory at sea. As a BU1 or BUC, you will be expected to know the information in this training manual and to perform your assigned tasks. The degree of success of the Navy will depend in part on your ability and the manner in which you perform your duties.

This training manual was prepared by the Naval Training Publications Detachment, Washington, D.C., for the Chief of Naval Education and Training. Information provided by other government agencies and numerous manufacturers is gratefully acknowledged. Technical assistance was provided by the Civil Engineering Support Office of the Naval Facilities Engineering Command, Port Hueneme, California; the Naval Examining Center; the Naval Schools Construction, Port Hueneme, California; the Naval Schools Construction, Davisville, Rhode Island; and the Naval Construction Training Unit, Gulfport, Mississippi.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CREDITS

The materials listed below are included in this edition of *Builder 1 & C* through the courtesy of the designated sources. Permission to use the material is gratefully acknowledged. Permission to reproduce illustrations and other materials in this publication must be obtained from the sources.

SOURCE	MATERIALS
John T. Wiley and Sons, Inc.	Figures 8-39, 8-40, 8-41, and 8-44
Portland Cement Association	Figures 4-27 and 4-28
The Associated General Contractors of America	Figures 3-29 through 3-42 and supporting textual material. (See pages 75 through 93.)

CHAPTER 1

DUTIES AND RESPONSIBILITIES

This training manual is designed to help you meet the occupational qualifications for advancement to Builder First Class and Chief Builder. Chapters 2 through 11 of this training manual deal with the technical subject matter of the Builder rating. The remainder of this chapter provides introductory information that will aid you in your preparation for advancement as well as acquaint you with the scope of the Builder rating and the types of billets to which you can be assigned. It is strongly recommended that you study this chapter carefully before beginning intensive study of the chapters that follow.

REWARDS AND RESPONSIBILITIES

Advancement brings both increased rewards and increased responsibilities. The time to start looking ahead and considering the rewards and the responsibilities of advancement is right now, while you are preparing for advancement to BU1 or BUC.

By this time, you are probably well aware of many of the advantages of advancement—higher pay, greater prestige, more interesting and challenging work, and the satisfaction of getting ahead in your chosen career. By this time, also, you have probably discovered that one of the most enduring rewards of advancement is the personal satisfaction you find in developing your skills and increasing your knowledge.

The Navy also benefits by your advancement. Highly trained personnel are essential to the functioning of the Navy. By each advancement you increase your value to the Navy in two ways. First, you become more valuable as a technical specialist in your own rating. And second, you become more valuable as a person who can supervise, lead, and train others and thus make far reaching and long lasting contributions to the Navy.

In large measure, the extent of your contribution to the Navy depends upon your willingness and ability to accept increasing responsibilities as you advance. When you assumed the duties of a BU3, you began to accept a certain amount of responsibility for the work of others. With each advancement, you accept an increasing responsibility in military matters and in matters relating to the occupational requirements of the Builder rating.

You will find that your responsibilities for military leadership are about the same as those of petty officers in other ratings, since every petty officer is a military person as well as a technical specialist. Your responsibilities for technical leadership are special to your rating and are directly related to the nature of your work. Erecting a structure is a job of vital importance, and it's a teamwork job, the supervision of which requires a special kind of leadership ability that can only be developed by personnel who have a high degree of technical competence and a deep sense of personal responsibility.

Certain practical details that relate to your responsibilities for management, supervision, and training are discussed in other chapters of this training manual. At this point, let's consider some of the broader aspects of your increasing responsibilities for military and technical leadership.

YOUR RESPONSIBILITIES WILL EXTEND BOTH UPWARD AND DOWNWARD. Both officers and enlisted personnel will expect you to translate the general orders given by officers into detailed, practical on-the-job language that can be understood and followed even by relatively inexperienced personnel. In dealing with your juniors, it is up to you to see that they perform their work properly. At the same time, you must be able to explain to officers any important needs or problems of the enlisted men.

YOU WILL HAVE REGULAR AND CONTINUING RESPONSIBILITIES FOR TRAINING. Even if you are fortunate enough to have a number of highly skilled and well trained Builders, you will still find that training is necessary. For example, you will always be responsible for training lower rated men for advancement. Also, some of your best workers may be transferred and inexperienced or poorly trained personnel may be assigned to you. Or a particular job may call for skills that none of your personnel have. These and similar problems require you to be a training specialist who can conduct formal and informal training programs to qualify personnel for advancement and who can train individuals and groups in the effective execution of assigned tasks.

YOU WILL HAVE INCREASING RESPONSIBILITIES FOR WORKING WITH OTHERS. As you advance to BU1 and then to BUC, you will find that many of your plans and decisions affect a large number of persons. It becomes increasingly important, therefore, to understand the duties and responsibilities of others. Every petty officer in the Navy is a technical specialist in his own field. Learn as much as you can about the work of other ratings, and plan your own work so that it will fit in with the overall mission of the organization.

AS YOUR RESPONSIBILITIES INCREASE, YOUR ABILITY TO COMMUNICATE CLEARLY AND EFFECTIVELY MUST ALSO INCREASE. The basic requirement for effective communication is a knowledge of your own language. Use correct language in speaking and writing. Remember that the basic purpose of all communication is understanding. To lead, supervise, and train others, you must be able to speak and write in such a way that others can understand exactly what you mean.

A second requirement for effective communication in the Navy is a sound knowledge of the Navy way of saying things. Some Navy terms have been standardized for the purpose of ensuring efficient communication. When a situation calls for the use of standard Navy terminology, use it.

Still another requirement of effective communication is precision in the use of technical terms. A command of the technical language of the Builder rating will enable you to receive and convey information accurately and to exchange ideas with others. A person who does not understand the precise meaning of terms used in connection with the work of his own rating is at a disadvantage when he tries to read official publications relating to his work. He is also at a great disadvantage when he takes the written examinations for advancement. Although it is always important for you to use technical terms correctly, it is particularly important when you are dealing with lower rated men. Sloppiness in the use of technical terms is likely to be very confusing to an inexperienced man.

YOU WILL HAVE INCREASED RESPONSIBILITIES FOR KEEPING UP WITH NEW DEVELOPMENTS. Practically everything in the Navy–policies, procedures, equipment, publications, systems–is subject to change and development. As a BU1, and even more so as a BUC, you must keep yourself informed about all changes and new developments that might affect your rating or your work.

Some changes will be called directly to your attention, but others you will have to look for. Try to develop a special kind of alertness for new information. See that you are well informed as to available sources of technical information. And, make a continuing effort to keep up to date on construction methods and equipment. New methods and new equipment are constantly being devised, and existing methods and equipment are subject to modification. If you look back over the history of construction since the end of World War II, you will note a number of important changes which have occurred during this time.

The tilt-up method of erecting concrete walls, for example, was practically unknown at the end of World War II, but is now used extensively. The board sheathing most generally used for forms at the end of World War II has been almost entirely supplanted by plywood. Prestressing for concrete was relatively unknown in 1946. Much of the current paving-train method of highway paving has been devised since that time. Various new and better mixing machines for concrete, mortar, and plaster have come out. Gun-setting of nails in concrete and masonry has been devised. Drop-hammers for pile-driving have given way almost totally to steam/air, diesel, and vibratory hammers. New types of floor tile have appeared. These are only a few of the changes which have occurred; they are noted here simply to show that changes may constantly be expected.

THE BUILDER RATING

In general terms, Builders plan, supervise, and perform tasks required in the construction, maintenance and repair of wooden, concrete, and masonry structures, concrete pavements, and waterfront and underwater structures. Greater insights into the diversity and complexity of these tasks can be gained by careful examination of the Quals for the Builder rating listed in the *Manual of Qualifications for Advancement* (discussed later in this chapter). Looking at these tasks from an organizational viewpoint, you can see that your involvement is based not only on your pay grade but also on the positions or billets to which the responsibility for these tasks is assigned.

ASSIGNMENT WITH BATTALIONS

The largest concentration of billets for BU1 and BUC are allotted to Naval Mobile Construction Battalions. In a battalion, a BU1 or BUC usually serves in a construction company as supervisor of construction crews. A few Builders of high caliber may also be selected to serve with Amphibious Construction Battalions or Special SEABEE Teams. Occasionally, a BUC may serve as the COMPANY CHIEF. Although it is an E8/E9 billet, the senior enlisted man in the company may be assigned the duties of the Company Chief. If is not possible to cover completely the areas of responsibility of the Company Chief in this manual, however, the following information will serve as a guide in acquainting you with his duties in regards to supervision, personnel administration, training, and military functions.

As the senior enlisted man in the company, the Company Chief will serve as the principal enlisted assistant to the Company Commander. His duties will be to:

1. Execute and enforce the policies of the Company Commander.
2. Supervise the clerical and administrative details of the company including the preparation of company correspondence, time cards, material requests and the maintenance of an up-to-date disaster control, bill, fire bill, watch bill, and company organization chart.
3. Inspect company projects to ensure that good working practices are employed and that manpower, equipment, and materials are being properly utilized; report the results of these inspections to the Company Commander, including the status of all matters pertaining to the projects; and make recommendations. if needed, that will improve working conditions or efficiency as well as assist the Company Commander in maintaining good working relations with other companies.
4. Assist the Company Commander in contracting S-2 (Battalion Plans and Training) personnel and in coordinating the assignment of company personnel to training designed to establish the company capability at the required level.
5. Maintain a company library consisting of publications pertaining to the Builder rating, such as technical manuals, manufacturers' manuals, trade magazines, and Naval training publications that will aid company personnel in preparing for advancement.
6. Assist in ceremonies, briefings, conferences, and other functions as designated by the Company Commander.
7. Assist in the assignment of personnel to weapons and positions in the company military organization.
8. Assist the Company Commander in disciplinary matters; ensure satisfactory scheduling of company personnel going on leave and R&R trips; encourage individual study and motivate eligible personnel to take advantage of programs for which they may qualify (i.e., SCORE and ADCOP); and coordinate company recreation projects such as parties and athletic events.

The success which the company achieves will depend upon the degree of coordination and cooperation developed within the company. To effectively promote this development the Company Chief must meet additional requirements in the management field. He must maintain initiative and use sound judgement in the guidance of human resources to attain the ojbective of good management. He must have the faculty for working in harmony with officers and other petty officers. He must be able to communicate ideas effectively (orally and in writing) at all levels. He must possess a comprehensive understanding of Navy organization, the mission of the battalion, and the working organization at the company level.

Outside of construction battalions, Builders may be assigned to recruiting duty, recruit training, and Naval Reserve training. A limited number of particularly well qualified Builders are also given assignments to instruct in Navy schools; to assist in making up the Navy-wide advancement examinations at the Naval Examining Center, Great Lakes, Ill.; to assist in the preparation of Rate Training Manuals (like this one) and other materials at the Naval Training Publications Detachment, Washington, D.C.; and to perform other highly specialized duties where their technical knowledge and supervisory abilities can be utilized effectively for the needs of the service, such as in public works management.

ASSIGNMENT WITH THE PUBLIC WORKS DEPARTMENT

At a shore activity, either within the United States or overseas, you may be assigned to duty in the Public Works Department (PWD). The standard organization for a PWD is shown in figure 1-1. Most of the jobs handled by Builders assigned to the PWD are in the Maintenance Control Division, an administrative division, and the Maintenance Division, an operating division. See figures 1-2 and 1-3. Of course, your duties may vary from one activity to another, but the discussion here will acquaint you with the duties and responsibilities associated with the various positions to which you may be assigned at a Public Works Activity.

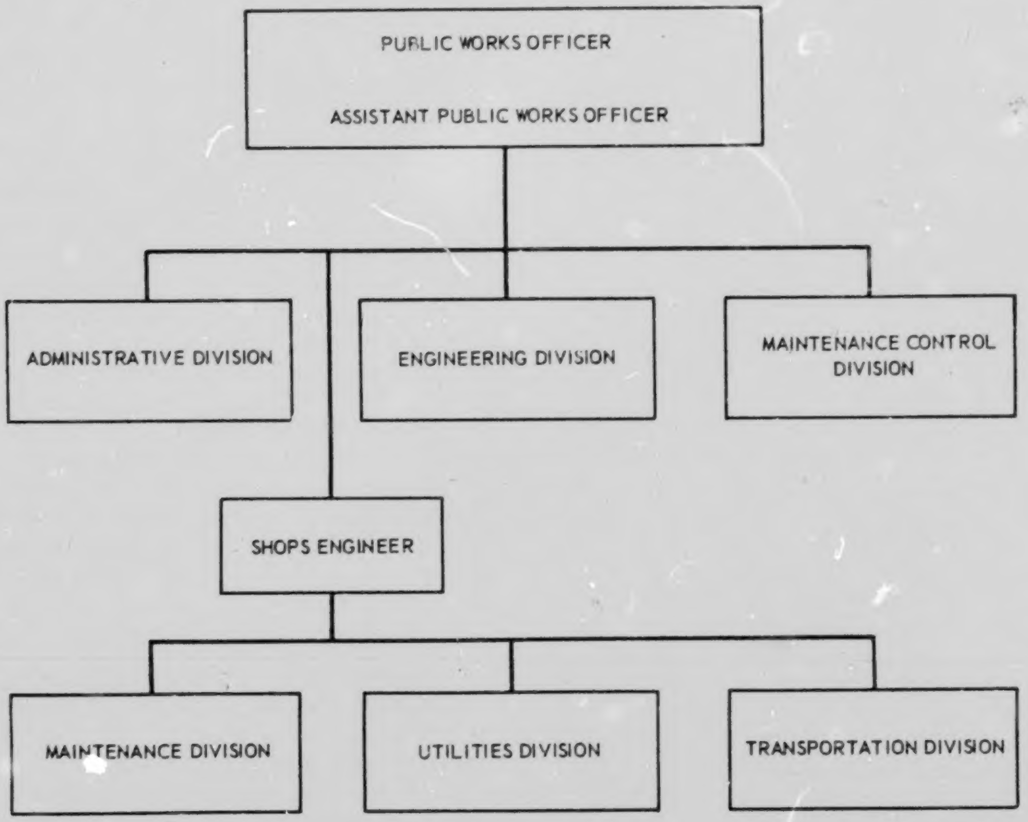
Maintenance Control Division

This is the one division in the PWD whose entire effort is directed toward maintenance management. Its existence is based on the premise that the functions of inspection, work reception, job planning and estimating, and work input control will be more successfully administered, and will have a more positive managing effect on maintenance, when they are assigned to a staff division rather than a group concerned primarily with the performance of maintenance work.

As a BU1, you may be assigned to the Planning and Estimating (P&E) Branch of the Maintenance Control Division (MCD) to serve in the capacity of PLANNER/ESTIMATOR. The P&E Branch is responsible for overall job planning and preparing estimates for work to be accomplished, and for initiating and expediting job orders for work performed by operating divisions in the PWD. This Branch:

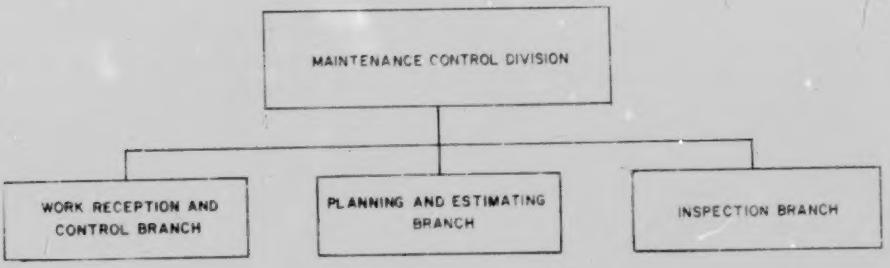
1. Prepares manpower and material estimates for work generated from the Inspection Branch as a result of a continuous inspection program or other work requests received from the Work Reception and Control Branch.
2. Compiles estimating information designed to improve estimating techniques for labor and material costs.
3. Plans maintenance work.
4. Provides necessary data to assist the Director, MCD, or the Public Works Officer in deciding whether to approve work authorization documents.
5. Arranges and presents job specifications that are complete enough to permit the cognizant Work Center supervisor to assign personnel to a job without resurveying the job site.
6. Determines the necessity for plans and working drawings, and obtains them from the Engineering Division.
7. Specifies the type of material required for each job order.
8. Reviews abnormal deviations from estimates when attributable to the planning and estimating functions and recommends appropriate corrections to the Director, MCD.

Once jobs have been assigned to the branch for an estimate, the Branch Manager then


PUBLIC WORKS OFFICER
ASSISTANT PUBLIC WORKS OFFICER
ADMINISTRATIVE DIVISION
ENGINEERING DIVISION
MAINTENANCE CONTROL DIVISION
SHOPS ENGINEER
MAINTENANCE DIVISION
UTILITIES DIVISION
TRANSPORTATION DIVISION

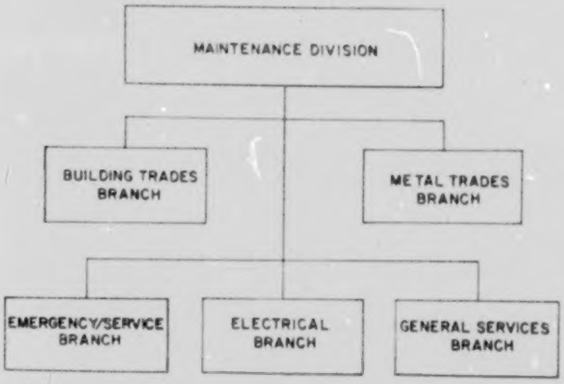
16.8

Figure 1-1. —Public Works Department Organization Chart.


MAINTENANCE CONTROL DIVISION
WORK RECEPTION AND CONTROL BRANCH
PLANNING AND ESTIMATING BRANCH
INSPECTION BRANCH

117.302

Figure 1-2. —Maintenance Control Division Organization Chart.



117.303

Figure 1-3. —Maintenance Division Organization Chart.

designates the planner/estimator who will be responsible for the final plans and estimate of the job. Typical procedures are for the Planner/Estimator to define the scope of the work to be accomplished and to determine which crafts are involved in the job. A good, clear, and brief description of the entire job is then entered under the General Job Description of the Estimate (Controlled Maintenance) NAVDOCKS, Form 2353 (figure 1-4). The job is then divided into phases by craft, or within a craft, when a finer breakdown is required for planning and scheduling. Then each Planner/Estimator prepares a Job Phase Calculation Sheet, NAVFAC Form 9-11014/23 (figure 1-5), for each phase under his responsibility, including sketches, plans, specifications or other data. The description of each job phase should be written just as it is to appear on the job order. The same Planner/Estimator responsible for the work content of the job collects all phases in the order they will appear on the Job Order, and prepares the Estimate. The description of the entire job and each phase must be clear enough as to scope and nature of work to be performed so as not to create any misunderstanding regarding work accomplishment. The Estimate which includes the Job Phase Calculation Sheets is then presented to the Supervisor of the P&E Branch and MCD for review.

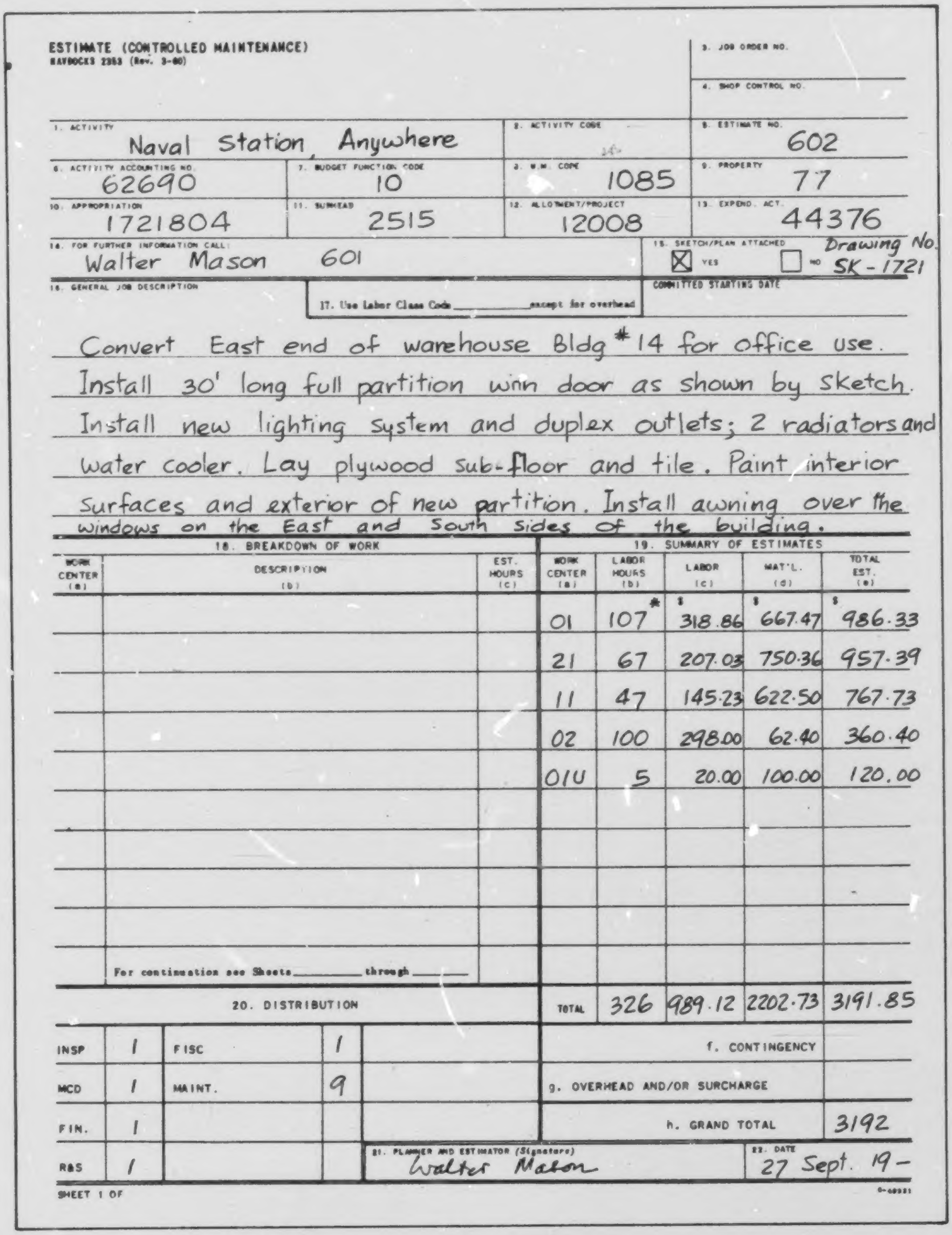
When reviewed and approved, the Estimate is transmitted to the Work Reception and Control Branch for typing of the Job Order and its distribution to the various crafts and supervisors. The information on the Job Order (NAVDOCKS Form 2356) and the Job Order Continuation Sheet (NAVDOCKS Form 2357) will be the same as that on the Estimate, and the Job Phase Description will be the same as those on the Job Phase Calculation Sheets. See figure 1-6. The job phases will be arranged on the Job Order in the sequence in which they will be scheduled or accomplished and submitted to the Director, MCD for approval. Upon approval, the completed Job Order is released to the Maintenance Division for purchase of material, scheduling, and accomplishment of work.

Maintenance Division

The majority of positions held by Builders in the PWD are in the Maintenance Division. The Maintenance Division is responsible for the administration and operation of the maintenance shops, usually referred to as Work Centers or Craft Shops, and for the Maintenance and repair of public works and public utilities.

As a BU1, you may be assigned the duties of the MAINTENANCE SCHEDULER or SHOP PLANNER in the office of the Division Director, or as a SHOP SUPERVISOR in the Building Trades Branch. BUCs are usually assigned the duties of the BRANCH MANAGER in the Building Trades Branch. It is not possible to cover completely the areas of responsibilities of each of these positions; however, the following information will serve as a guide in acquainting you with the administrative function of each position.

The principal assistant to the Director of the Maintenance Division is the Maintenance Scheduler, normally referred to as the MASTER SCHEDULER, who performs overall job planning at division level, including the scheduling of work by Work Centers, reporting major deviations from established schedules to the Director, alerting work center and branch supervisors of excessive variances between actual and estimated labor or material costs, maintaining in current status the Master Schedule Board, and improving scheduling controls and techniques. Where workload requires, many planning functions can be performed by a staff of SHOP PLANNERS.



ESTIMATE (CONTROLLED MAINTENANCE)
NAVDOCKS 2353 (Rev. 3-60)

3. JOB ORDER NO.
4. SHOP CONTROL NO.

1. ACTIVITY Naval Station, Anywhere		2. ACTIVITY CODE	5. ESTIMATE NO. 602
6. ACTIVITY ACCOUNTING NO. 62690	7. BUDGET FUNCTION CODE 10	8. W.M. CODE 1085	9. PROPERTY 77
10. APPROPRIATION 1721804	11. SUBHEAD 2515	12. ALLOTMENT/PROJECT 12008	13. EXPEND. ACT. 44376
14. FOR FURTHER INFORMATION CALL: Walter Mason 601		15. SKETCH/PLAN ATTACHED ☒ YES ☐ NO	Drawing No. SK-1721

16. GENERAL JOB DESCRIPTION

17. Use Labor Class Code __________ except for overhead

COMMITTED STARTING DATE

Convert East end of warehouse Bldg #14 for office use. Install 30' long full partition with door as shown by sketch. Install new lighting system and duplex outlets; 2 radiators and water cooler. Lay plywood sub-floor and tile. Paint interior surfaces and exterior of new partition. Install awning over the windows on the East and South sides of the building.

18. BREAKDOWN OF WORK

WORK CENTER (a)	DESCRIPTION (b)	EST. HOURS (c)
	For continuation see Sheets ______ through ______	

19. SUMMARY OF ESTIMATES

WORK CENTER (a)	LABOR HOURS (b)	LABOR (c)	MAT'L. (d)	TOTAL EST. (e)
01	107*	$ 318.86	$ 667.47	$ 986.33
21	67	207.03	750.36	957.39
11	47	145.23	622.50	767.73
02	100	298.00	62.40	360.40
01U	5	20.00	100.00	120.00
TOTAL	326	989.12	2202.73	3191.85
			f. CONTINGENCY	
			g. OVERHEAD AND/OR SURCHARGE	
			h. GRAND TOTAL	3192

20. DISTRIBUTION

INSP	1	FISC	1
MCD	1	MAINT.	9
FIN.	1		
R&S	1		

21. PLANNER AND ESTIMATOR (Signature) Walter Mason

22. DATE 27 Sept. 19–

SHEET 1 OF

0-48931

117.304

Figure 1-4. —Estimate (Controlled Maintenance).

JOB PHASE CALCULATION SHEET
NAVFAC 11014/23 (REV. 4-72)
S/N 0105-002-7801

*See NOTE below

WORK SITE

1. CRAFT PHASE NO.	2. JOB PHASE NO.	3. JOB IDENTITY NO.	4. DATE
1	1	602	19 Sept. 19-

5. WORK CENTER NO. AND TITLE
01 carpenters

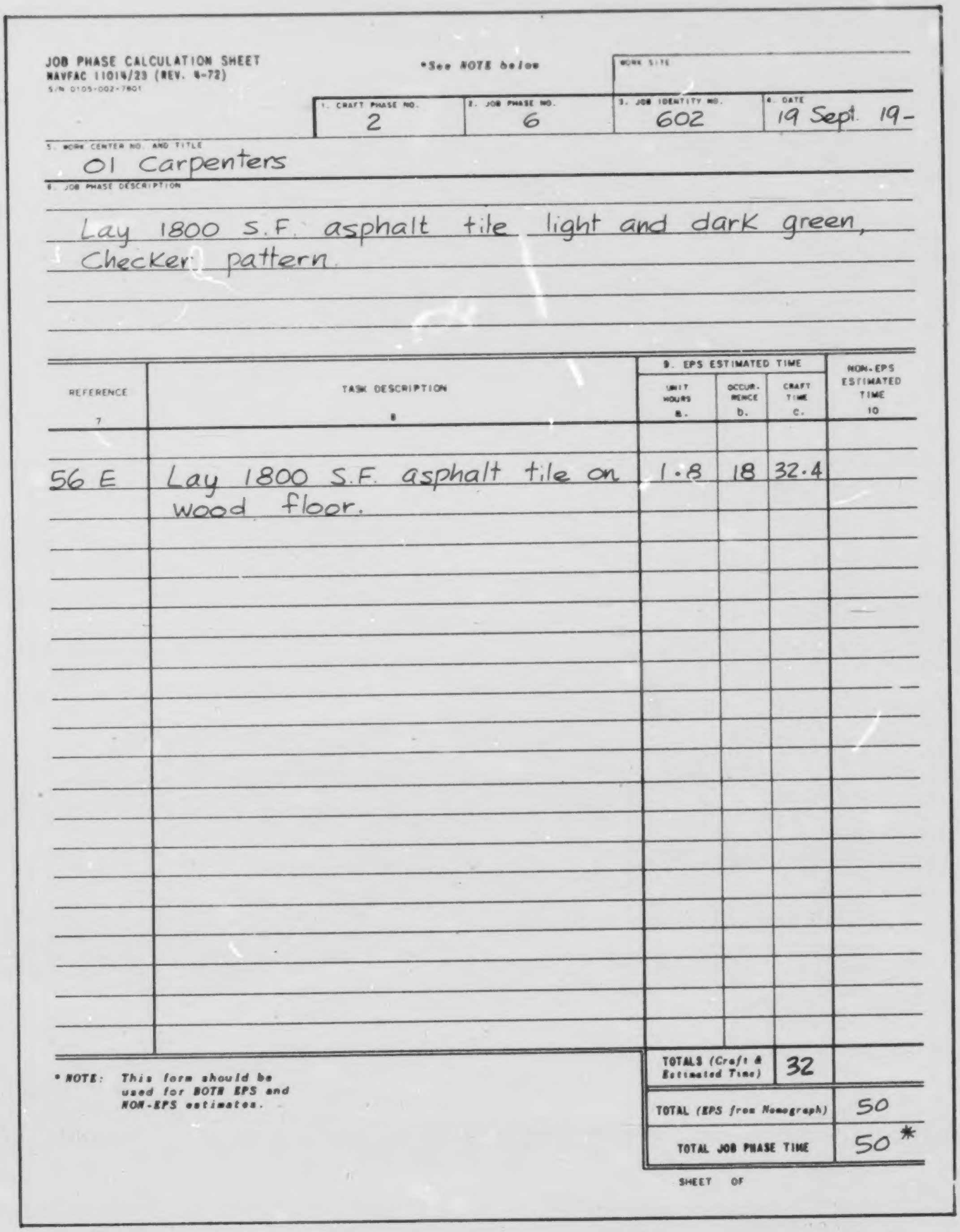
6. JOB PHASE DESCRIPTION
Construct 30' long, 12' high full partition, gypsum wall board both sides, 2" x 4" studs 24" O.C.; 5" baseboard, shoe molding, 3" ceiling cove molding both sides to match; install 2'-8" x 6'-8" door. Install 4" chair rail on interior walls and 1/4" Plywood Subfloor.

REFERENCE 7	TASK DESCRIPTION 8	9. EPS ESTIMATED TIME UNIT HOURS a.	OCCURRENCE b.	CRAFT TIME c.	NON-EPS ESTIMATED TIME 10
39L	Construct 30' long, 12' high partition 2" x 4" studs 24" O.C., gypsum board, shoe molding and 5" baseboard both sides, 1 door opening framed and closed.	16	1	16.0	
34 E	Install 3" ceiling cove molding each side partition (60. L. F.)	1.8	.6	1.1	
12 E	Hang 2'-8" x 6'-8" door in partition	1.8	1	1.8	
51 C	Install 4" chair rail on interior wall of office (180 L. F.)	.6	2.5	1.5	
22 E	Lay 1800 S.F 1/4" Plywood Subfloor	1.8	9.4	16.9	
			TOTALS (Craft & Estimated Time)	37	
			TOTAL (EPS from Nomograph)		57
			TOTAL JOB PHASE TIME		57 *

*NOTE: This form should be used for BOTH EPS and NON-EPS estimates.

SHEET OF

BEST COPY AVAILABLE



JOB PHASE CALCULATION SHEET
NAVFAC 11014/23 (REV. 4-72)
S/N 0105-002-7801

*See NOTE below

WORK SITE

1. CRAFT PHASE NO. 2	2. JOB PHASE NO. 6	3. JOB IDENTITY NO. 602	4. DATE 19 Sept. 19–

5. WORK CENTER NO. AND TITLE
01 Carpenters

6. JOB PHASE DESCRIPTION
Lay 1800 S.F. asphalt tile light and dark green, Checker pattern.

REFERENCE 7	TASK DESCRIPTION 8	9. EPS ESTIMATED TIME UNIT HOURS a.	OCCURRENCE b.	CRAFT TIME c.	NON-EPS ESTIMATED TIME 10
56 E	Lay 1800 S.F. asphalt tile on wood floor.	1.8	18	32.4	

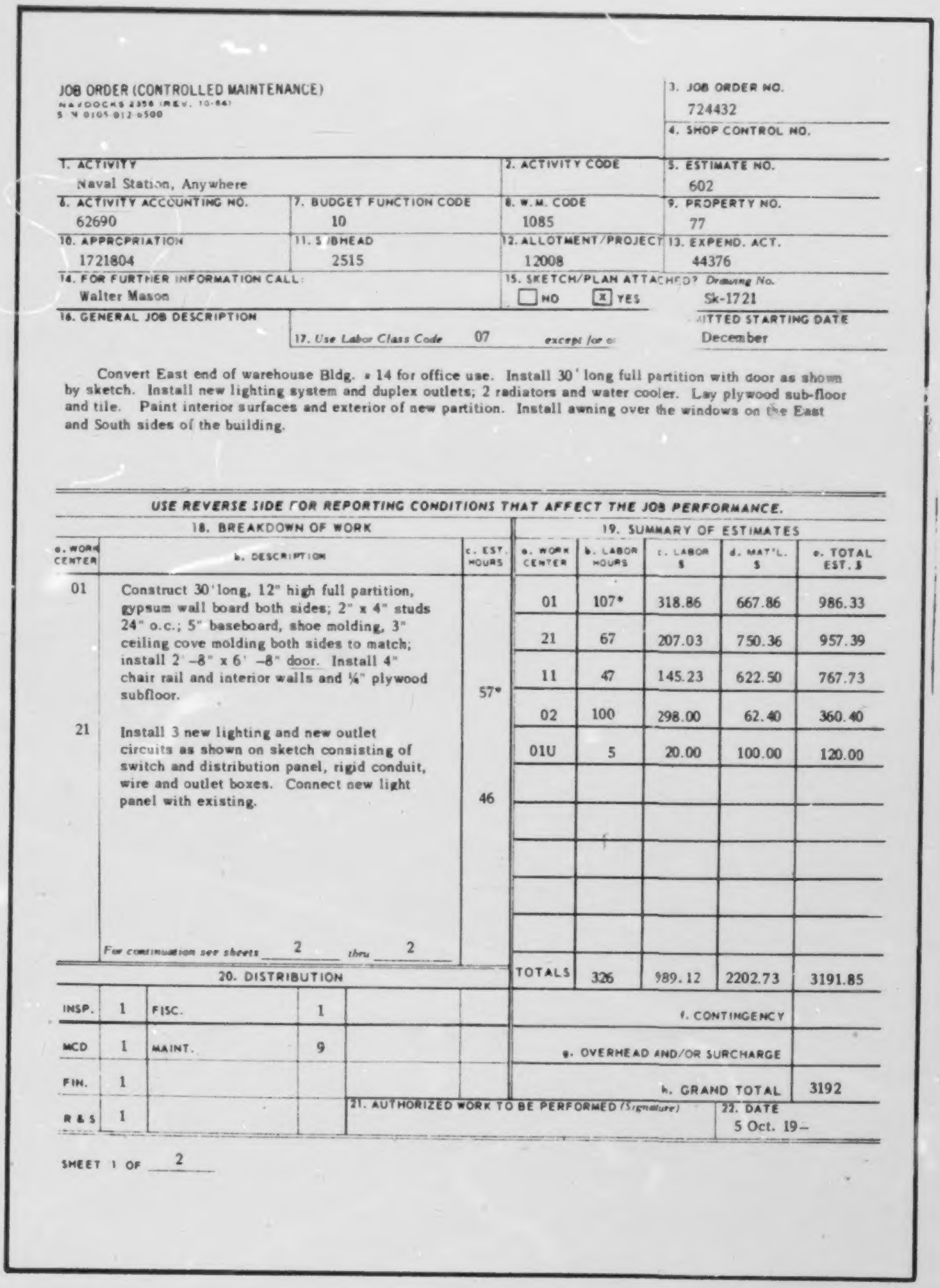
* NOTE: This form should be used for BOTH EPS and NON-EPS estimates.

TOTALS (Craft & Estimated Time)	32	
TOTAL (EPS from Nomograph)		50
TOTAL JOB PHASE TIME		50 *

SHEET OF

87.5

Figure 1-5. —Job Phase Calculation Sheets.



JOB ORDER (CONTROLLED MAINTENANCE)
NAVDOCKS 2356 (REV. 10-64)
S/N 0105-012-6500

3. JOB ORDER NO. 724432
4. SHOP CONTROL NO.

1. ACTIVITY Naval Station, Anywhere		2. ACTIVITY CODE	5. ESTIMATE NO. 602
6. ACTIVITY ACCOUNTING NO. 62690	7. BUDGET FUNCTION CODE 10	8. W.M. CODE 1085	9. PROPERTY NO. 77
10. APPROPRIATION 1721804	11. SUBHEAD 2515	12. ALLOTMENT/PROJECT 12008	13. EXPEND. ACT. 44376
14. FOR FURTHER INFORMATION CALL: Walter Mason		15. SKETCH/PLAN ATTACHED? ☐ NO ☒ YES	Drawing No. Sk-1721

16. GENERAL JOB DESCRIPTION

17. *Use Labor Class Code* 07 *except for o*

ITTED STARTING DATE December

Convert East end of warehouse Bldg. # 14 for office use. Install 30' long full partition with door as shown by sketch. Install new lighting system and duplex outlets; 2 radiators and water cooler. Lay plywood sub-floor and tile. Paint interior surfaces and exterior of new partition. Install awning over the windows on the East and South sides of the building.

USE REVERSE SIDE FOR REPORTING CONDITIONS THAT AFFECT THE JOB PERFORMANCE.

18. BREAKDOWN OF WORK

a. WORK CENTER	b. DESCRIPTION	c. EST. HOURS
01	Construct 30' long, 12" high full partition, gypsum wall board both sides; 2" x 4" studs 24" o.c.; 5" baseboard, shoe molding, 3" ceiling cove molding both sides to match; install 2' -8" x 6' -8" door. Install 4" chair rail and interior walls and ¼" plywood subfloor.	57*
21	Install 3 new lighting and new outlet circuits as shown on sketch consisting of switch and distribution panel, rigid conduit, wire and outlet boxes. Connect new light panel with existing.	46

For continuation see sheets 2 *thru* 2

19. SUMMARY OF ESTIMATES

a. WORK CENTER	b. LABOR HOURS	c. LABOR $	d. MAT'L. $	e. TOTAL EST. $
01	107*	318.86	667.86	986.33
21	67	207.03	750.36	957.39
11	47	145.23	622.50	767.73
02	100	298.00	62.40	360.40
01U	5	20.00	100.00	120.00
TOTALS	326	989.12	2202.73	3191.85
			f. CONTINGENCY	
			g. OVERHEAD AND/OR SURCHARGE	
			h. GRAND TOTAL	3192

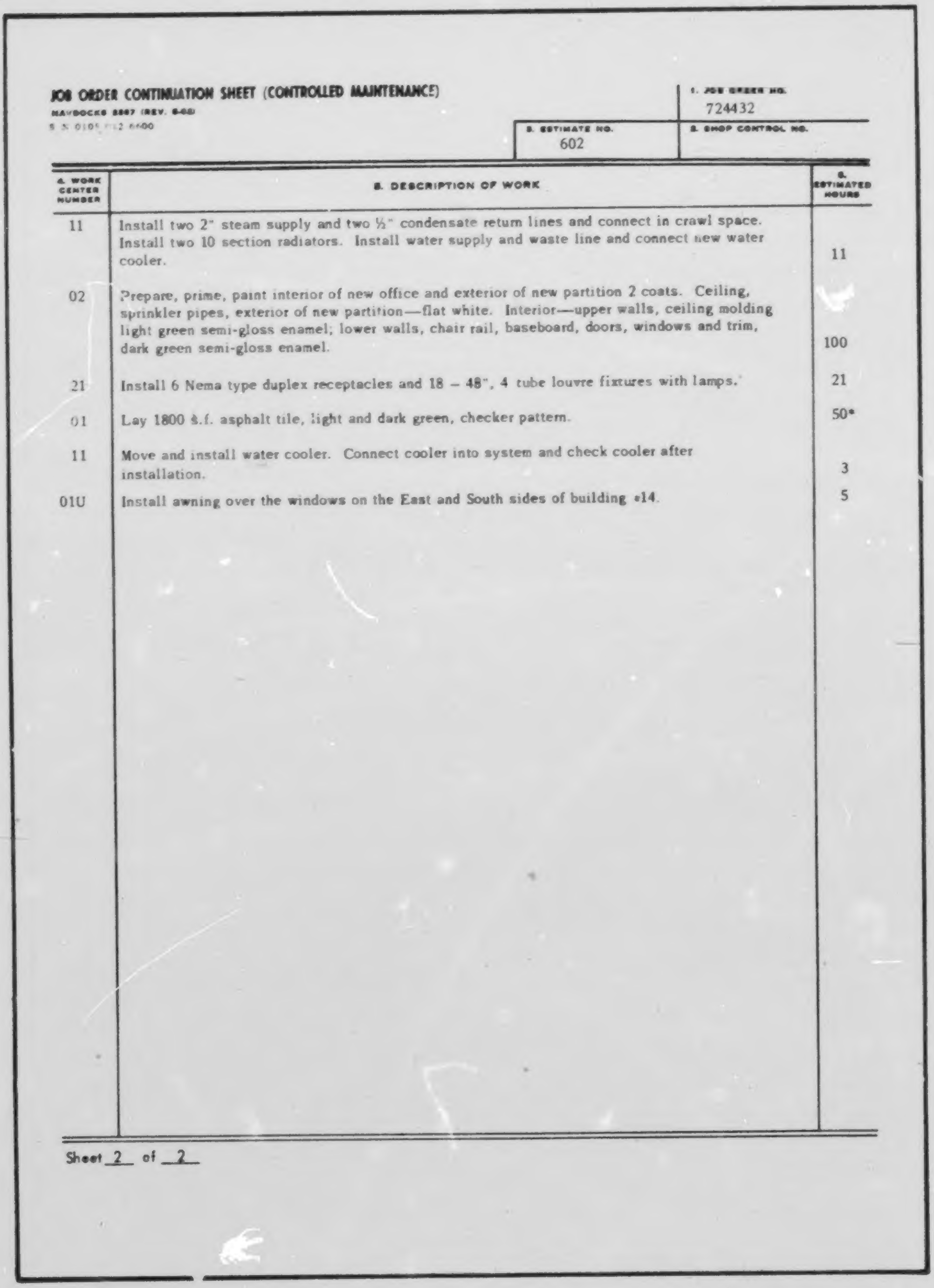
20. DISTRIBUTION

INSP.	1	FISC.	1		
MCD	1	MAINT.	9		
FIN.	1				
R & S	1				

21. AUTHORIZED WORK TO BE PERFORMED *(Signature)*

22. DATE 5 Oct. 19–

SHEET 1 OF 2



JOB ORDER CONTINUATION SHEET (CONTROLLED MAINTENANCE)
NAVDOCKS 2267 (REV. 8-60)
S N 0105 [illegible]12 6600

1. JOB ORDER NO. 724432
3. ESTIMATE NO. 602
2. SHOP CONTROL NO.

4. WORK CENTER NUMBER	5. DESCRIPTION OF WORK	6. ESTIMATED HOURS
11	Install two 2" steam supply and two ½" condensate return lines and connect in crawl space. Install two 10 section radiators. Install water supply and waste line and connect new water cooler.	11
02	Prepare, prime, paint interior of new office and exterior of new partition 2 coats. Ceiling, sprinkler pipes, exterior of new partition—flat white. Interior—upper walls, ceiling molding light green semi-gloss enamel; lower walls, chair rail, baseboard, doors, windows and trim, dark green semi-gloss enamel.	100
21	Install 6 Nema type duplex receptacles and 18 – 48", 4 tube louvre fixtures with lamps.	21
01	Lay 1800 s.f. asphalt tile, light and dark green, checker pattern.	50*
11	Move and install water cooler. Connect cooler into system and check cooler after installation.	3
01U	Install awning over the windows on the East and South sides of building #14.	5

Sheet 2 of 2

87.4

Figure 1-6. –Completed Job Order (Controlled Maintenance).

Some of these functions are:

1. Schedule starting and completion dates for each work phase, based on information regarding manpower; machine, tool, and equipment and material availability; current workload; priorities and deadlines; and weather conditions.
2. Coordinate scheduling for assigned work centers with master schedules established by Master Scheduler and with shop planners or supervisors in other shops engaged in the same job order.
3. Assist Master Scheduler in preparation and revision of master schedules for Maintenance Division, and in coordinating work flow among various work centers.
4. Clear with local authorities when clearance is required for demolition, line maintenance or other similar work.
5. Arrange for special police or fire protection for working crews when they arrive.
6. Arrange with the occupant to be ready for the working crews when they arrive.
7. Arrange for delivery and usability of equipment at the proper time on the job site.
8. Initiate requests for material procurement from shop stores or direct procurement by preparing detailed and complete lists of all items required from job specifications, plans, sketches, and related sources. Knowledge of the materials used in the work and of the actual work processes involved is essential.
9. Arrange for on-site delivery of material to coincide with scheduled or actual performance.
10. Arrange for return of material not used on the job.

The majority of the supervisory positions held by Builders in the Maintenance Division are in the Building Trades Branch. As a BU1, you may be assigned as SUPERVISOR of the carpentry, paint or other craft related Building Trades Shop. In this capacity, you should work closely with the Master Scheduler and Shop Planner to efficiently plan and schedule all jobs, and with the Planner/Estimator in planning complex jobs before they are written on job orders. A large percentage of the jobs performed by the maintenance forces requires work by various work centers or craft shops. Therefore, coordination is an integral part of every supervisor's job. Good work coordination by the various craft supervisors results in better and more economical job completion.

As a BUC, you may be asssigned as MANAGER of the Building Trades Branch. In this capacity, your duties will probably involve the planning, assigning, directing, coordinating, and expediting of all work performed by the Building Trades Branch, working in coordination with your subordinate supervisors, other shop supervisors, and the Master Scheduler. You should be able to analyze work schedules, plan work assignments, and explain work requirements to subordinate levels of supervision. You should have a working knowledge in the fields of management and shop practices. Among other things, you should be able to determine training needs for all levels of subordinates, supervisors, and workers.

As a supervisor in the Maintenance Division, you will encounter many types of forms and reports, most of which are standard to the system and some of which are standard only to a local activity. In either case they are representative of the tools with which you can satisfy the requirements of your position. No attempt is made here to acquaint you with any of these forms. The control of maintenance cannot be reduced to a manual of operations to meet every condition. When too much emphasis is placed upon procedures to achieve conformity, uniformity, or standardization, there is a tendency to lose sight of the main objectives. The objectives are obscured by over-zealous attention to procedures and reports. One of the prime objectives of maintenance management is to increase the productivity of the maintenance work force. The procedures, forms and reports are merely tools to help attain this objective. By careful study of the principles of supervision discussed in Chapter 2 and the principles of planning, estimating, and scheduling discussed in Chapter 3, you will be equipped with sufficient information to enable you to utilize the various forms in accordance with the objectives of maintenance management should you be assigned to a Public Works Activity.

REQUIREMENTS FOR ADVANCEMENT

In general, to qualify for advancement you must:

1. Have a certain amount of time in grade.
2. Complete the required military and occupational training courses.
3. Demonstrate the ability to perform all the PRACTICAL requirements for advancement indicated in the Record of Practical Factors, NavPers 1414/1 BU (formerly Nav Pers 760).
4. Be recommended by your commanding officer.
5. Demonstrate your KNOWLEDGE by passing a written examination based on (a) the military requirements for advancement and (b) the occupational qualifications for advancement.

FINAL MULTIPLE

Advancement is not automatic. Meeting all the requirements makes you eligible for advancement but does not guarantee your advancement. The number of men in each rate and rating is controlled on a Navy-wide basis. Therefore, the number of men that may be advanced is limited by the number of vacancies that exist. When the number of men passing the examination exceeds the number of vacancies, some system must be used to determine which men may be advanced and which may not. The system used is the "final multiple" and is a combination of three types of advancement systems.

Merit rating system
Personnel testing system
Longevity, or seniority system

The Navy's system provides credit for performance, knowledge, and seniority, and, while it cannot guarantee that any one person will be advanced, it does guarantee that all men within a particular rating will have equal advancement opportunity.

The following factors are considered in computing the final multiple:

POINTS	FACTOR	WEIGHT
80 (MAX)	Examination Score	40 %
50 (MAX)	Performance (Average of marks received)	25 %
20 (MAX)	Total Active Service (1 per year)	10 %
20 (MAX)	Time in Present Grade (2 per year)	10 %
15 (MAX)	Medals and Awards	7.5%
15 (MAX)	PNA (Maximum 3 per exam cycle)	7.5%
200 (MAX POSSIBLE)		100 %

All of the above information (except the examination score and the PNA factor) is submitted to the Naval Examining Center with your examination answer sheet. After grading, the examination scores, for those passing, and the PNA points (additional points awarded to those who previously passed the examination but were not advanced) are added to the other factors to arrive at the final multiple. A precedence list, which is based on final multiples, is then prepared for each pay grade within each rating. Advancement authorizations are then issued, beginning at the top of the list, for the number of men needed to fill the existing vacancies.

PNA FACTOR

PNA points are comprised of two subfactors, Navy-wide examination score and performance mark standing. Individually, both subfactors are weighed in relation to a member's standing among all those who participated in his specific examination rate for a given cycle. In the case of the performance mark standing subfactor, individual performance mark averages submitted to the Naval Examining Center are used as the basis for determining the member's performance standing in relation to his contemporaries. For those who pass examinations but are not advanced, additional points will be credited to their final multiple for succeeding examinations in accordance with the schedule established for each subfactor as follows:

EXAMINATION SCORE	POINTS
70 through 80	1.5
60 through 69	1.0
Passing through 59	.5

PERFORMANCE MARK AVERAGE	POINTS
Top 25 Percent	1.5
Upper 25 to 50 Percent	1.0
Lower 50 to 25 Percent	.5
Bottom 25 Percent	.0

NOTE: Maximum of 3 multiple points per cycle.
Maximum of 15 multiple points after 5 exam cycles.

PNA points will be awarded as follows: A maximum of three points can be accrued each examination cycle. After five examination cycles, candidates will be eligible for the maximum number of points (15). Subsequent to complete implementation, each candidate's PNA factor will be computed based on the points received in the five most recent examinations competed in, out of the last six examinations. This will allow candidates to miss one examination and still be eligible for the maximum award.

KEEPING CURRENT ON ADVANCEMENT

Remember that the requirements for advancement may change from time to time. Check with your division officer or with your training officer to be sure you have the most recent requirements when you are preparing for advancement and when you are helping lower rated men to prepare for advancement.

To prepare for advancement, you need to be familiar with (1) the military requirements and the occupational qualifications given in the *Manual of Qualifications for Advancement*, NavPers 18068-C; (2) the Record of Practical Factors, NavPers 1414/1 BU; (3) appropriate Rate Training Manuals; and (4) any other material that may be required or recommended in the current edition of the *Bibliography for Advancement Study*, NAVTRA 10052. These materials are discussed later in the section of this chapter that deals with sources of information.

SCOPE OF THIS TRAINING MANUAL

Before studying any book, it is a good idea to know the purpose and the scope of the book. Here are some things you should know about this training manual:

- It is designed to give you information on the occupational qualifications for advancement to BU1 and BUC.

- It must be satisfactorily completed before you can advance to BU1 or BUC, whether you are in the regular Navy or in the Naval Reserve.

- It is NOT designed to give you information on the military requirements for advancement to PO1 or CPO. Rate Training Manuals that are specially prepared to give information on the military requirements are discussed in the section of this chapter that deals with sources of information.

- It is NOT designed to give you information that is related primarily to the qualifications for advancement to BU3 and BU2. Such information is given in *Builder 3 & 2*, NavPers 10648-F.

- The occupational Builder qualifications that were used as a guide in the preparation of this training manual were those promulgated in the *Manual of Qualifications for Advancement*, NavPers 18068-C, change 1. Therefore, changes in the Builder qualifications occurring after this change may not be reflected in the information given in this training manual. Since your major purpose in studying this training manual is to meet the qualifications for advancement to BU1 of BUC, it is important for you to obtain and study a set of the most recent Builder qualifications.

- This training manual includes information that is related to both the KNOWLEDGE FACTORS and the PRACTICAL FACTORS of the qualifications for advancement to BU1 and BUC. However, no training manual can take the place of actual on-the-job experience for developing skill in the practical factors. The training manual can help you understand some of the whys and wherefores, but you must combine knowledge with practical experience before you can develop the required skills. The Record of Practical Factors, NavPers 1414/1 BU, should be utilized in conjunction with this training manual whenever possible.

- Chapters 2 through 11 of this training manual deal with the occupational subject matter of the Builder rating. Before studying these chapters, study the table of contents and note the arrangement of information. Information can be organized and presented in many different ways. You will find it helpful to get an overall view of the organization of this training manual before you start to study it.

SOURCES OF INFORMATION

It is very important for you to have an extensive knowledge of the references to consult for detailed, authoritative, up-to-date information on all subjects related to the military requirements and to the occupational qualifications of the Builder rating.

Some of the publications discussed here are subject to change or revision from time to time–some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been entered.

Official publications and directives carry abbreviations and numbers which identify the source of the document and its subject matter. An abbreviation designates the publisher (e.g., NAVPERS, NAVFAC), and the numerals that follow indicate the series of related issuances to which the publication belongs. The letter following the numerals designates the edition.

As a result of the establishment of the Naval Training Command, new editions of rate training manuals, correspondence courses, curricula, and other training publications formerly designated with the abbreviation NAVPERS are being designated with NAVTRA. The numerals and the edition designators remain unchanged. This training manual, for instance, is NAVTRA 10649-F, which means that it is a publication of the Naval Training Command which succeeds a manual designated NAVPERS.

In this chapter and elsewhere in this text, training publications which already carry the new abbreviation are so listed; those not yet changed are listed as NAVPERS numbers.

Because you should always make it your responsibility to see that you are using the latest edition of any publication or directive, this training manual usually does not show the final letter referring to a publication or directive. ALWAYS USE THE LATEST EDITION.

BUPERS AND NAVTRA PUBLICATIONS

The BuPers and NAVTRA publications described here include some which are absolutely essential for anyone seeking advancement and some which, although not essential, are extremely helpful.

THE *QUALS MANUAL.*–The *Manual of Qualifications for Advancement*, NavPers 18068-C, (with changes), gives the minimum requirements for advancement to each rate within each rating. The *Quals Manual* lists the military requirements which apply to all ratings and the occupational qualifications that are specific to each rating.

The *Quals Manual* is kept current by means of numbered changes. These changes are issued more frequently than most Rate Training Manuals can be revised; therefore, the training manuals cannot always reflect the latest qualifications for advancement. When preparing for advancement, you should always check the LATEST *Quals Manual* and the LATEST changes to be sure that you know the current requirements for advancement.

When studying the qualifications for advancement, remember these three things:

1. The quals are the MINIMUM requirements for advancement to each rate within each rating. If you study more than the required minimum, you will of course have a great advantage when you take the written examination for advancement.
2. Each qual has a designated pay grade–E-4, E-5, E-6, E-7, E-8, or E-9. You are responsible for meeting all quals specified for advancement to the pay grade to which you are seeking advancement AND all quals specified for lower pay grades.
3. The written examinations for advancement to E-6 and above contain questions relating to the practical factors and the knowledge factors of BOTH military/leadership requirements and occupational qualifications. Personnel preparing for advancement to E-4 or E-5 must pass a separate military/leadership examination prior to participation in the Navy-wide occupational examination. The military/leadership examinations for the E-4 and E-5 levels are given according to a schedule prescribed by the commanding officer. Candidates are required to pass the applicable military/leadership examination only once.

RECORD OF PRACTICAL FACTORS.–A special form known as the Record of Practical Factors, NavPers 1414/1 BU, is used to record the satisfactory completion of the practical factors, both military and occupational, listed in the *Quals Manual*. Either this form or its predecessor, NavPers 760, is available for each rating. The old form will continue to be used until supplies are exhausted. Whenever a person demonstrates his ability to perform a practical factor, appropriate entries must be made in the DATE and INITIALS column. As a BU1 or BUC, you will often be required to check the practical factor performance of lower rated men and to report the results to your supervising officer. To facilitate record keeping, group records of practical factors are often maintained by each activity. Entries from the group records must, of course, be transferred to each individual's Record of Practical Factors at appropriate intervals.

As changes are made periodically to the *Quals Manual*, new forms of NavPers 1414/1 BU are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the *Quals Manual*. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement. Keep this in mind when you are training and supervising lower rated personnel. If a man demonstrates proficiency in some skill which is not listed in the Builder quals but which falls within the general scope of the rating, report this fact to the supervising officer so that an appropriate entry can be made.

The Record of Practical Factors should be kept in each man's service record and should be forwarded with the service record to the next duty station. Each man should also keep a copy of the record for his own use.

It is advisable for each individual to review his service record, approximately 15 days prior to any type of transfer, to ensure that his practical factor sheet and other important papers have been entered in his record.

NAVTRA 10052.–*Bibliography for Advancement Study*, NAVTRA 10052, is a very important publication for anyone preparing for advancement. This publication lists required and recommended Rate Training Manuals and other reference material to be used by personnel working for advancement. NAVTRA 10052 is revised and issued once each year by the Naval Training Command. Each revised edition is identified by a letter following the NAVTRA number. When using this publication, be SURE you have the most recent edition.

The required and recommended references are listed by rate level in NAVTRA 10052. It is important to remember that you are responsible for all references at lower rate levels, as well as those listed for the rate to which you are seeking advancement.

Rate Training Manuals that are marked with an asterisk (*) in NAVTRA 10052 are MANDATORY at the indicated rate levels. A mandatory training manual may be completed by (1) passing the appropriate Enlisted Correspondence

Course based on the mandatory training manual, (2) passing locally prepared tests based on the information given in the mandatory training manual, or (3) in some cases, successfully completing an appropriate Navy school.

It is important to notice that all references, whether mandatory or recommended, listed in NAVTRA 10052 may be used as source material for the written examinations, at the appropriate rate levels.

RATE TRAINING MANUALS.–Rate Training Manuals are written for the specific purpose of helping personnel prepare for advancement. Some manuals are general in nature and are intended for use by more than one rating; others (such as this one) are specific to the particular rating.

Rate Training Manuals are revised from time to time to bring them up to date. The revision of a Rate Training Manual is identified by a letter following the NavPers number. You can tell whether a Rate Training Manual is the latest edition by checking the NavPers number and the letter following the number in the most recent edition of the *List of Training Manuals and Correspondence Courses*, NAVTRA 10061 (revised).

There are three Rate Training Manuals that are specially prepared to present information on the military requirements for advancement. These manuals are:

Basic Military Requirements, NAVTRA 10054 (current edition).

Military Requirements for Petty Officer 3 & 2, NAVTRA 10056 (current edition).

Military Requirements for Petty Officer 1 & C, NAVTRA 10057 (current edition).

Each of the military requirements manuals is mandatory at the indicated rate levels. In addition to giving information on the military requirements, these three manuals give a good deal of useful information on the enlisted rating structure; how to prepare for advancement; how to supervise, train, and lead other men; and how to meet your increasing responsibilities as you advance.

Some of the Rate Training Manuals that may be useful to you when you are preparing to meet the occupational qualifications for advancement to BU1 and BUC are discussed briefly in the following paragraphs.

Tools and Their Uses, NavPers 10085 (current edition). This training manual contains a good deal of useful information on the care and use of various types of handtools and portable power tools commonly used in the Navy.

Blueprint Reading and Sketching, NavPers 10077 (current edition). This training manual contains useful information that will aid you in the reading and preparation of construction prints and drawings.

Applied Mathematics for Builders, NavPers 94416. This workbook when used in conjunction with the text, *General Mathematics for Construction Ratings* (NavPers 94415), forms a course of programmed instruction that is designed to help you learn the mathematics involved in the Builder rating.

Builder 3 & 2, NavPers 10648-F. Satisfactory completion of this training manual is required for advancement to BU3 and BU2. If you have met this requirement by satisfactorily completing an earlier edition of *Builder 3 & 2*, you should at least glance through the -F revision of the training manual. Much of the information given in this edition of *Builder 1 & C* is based on the assumption that you are familiar with the contents of *Builder 3 & 2*, NavPers 10648-F.

Rate Training Manuals prepared for other Group VIII (Construction) ratings are often a useful source of information. References to these training manuals will increase your knowledge of the duties and skills of other men in the Construction ratings. The training manuals prepared for Construction Electricians and Utilitiesmen are likely to be of particular interest to you, since nearly every building whose construction you supervise must be so constructed as to permit the installation of electrical and utility fixtures.

CORRESPONDENCE COURSES.–Most Rate Training Manuals and Officer Texts are used as the basis for correspondence courses. Completion of a mandatory training manual can be accomplished by passing the correspondence course that is based on the training manual. You will find it helpful to take other correspondence courses, as well as those that are based on mandatory training manuals. Taking a correspondence course helps you to master the information given in the training manual or text and also gives you a pretty good idea of how much you have learned from studying the manual. Both enlisted and officer correspondence courses are listed in the *List of Training Manuals and Correspondence Courses*, NAVTRA 10061 (revised).

NAVFAC PUBLICATIONS

A number of publications issued by the Naval Facilities Engineering Command (NAVFAC) which will be of interest to personnel in the Group VIII ratings are listed in the *Index of Naval Facilities Engineering Command Publications*, NAVFAC P-349 (updated semiannually). A publications program is one of the principal communications media used by NAVFAC to provide a ready reference of current technical and administrative data for use by its subordinate units. NAVFAC publications are listed in alphabetical and numerical order in NAVFAC P-349; copies of NAVFAC P-349 may be obtained through proper channels from the U.S. Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

NAVFAC publications that the BU will find useful include various operation and maintenance manuals, commonly referred to as MOs. You will be especially concerned with those MOs dealing with such subjects as roofing, painting, waterfront facilities, and structures. MOs provide information that will be beneficial to you in the maintenance of buildings and structures found at naval shore activities. Some of the design manuals, often called DMs, published by NAVFAC may also contain information of interest to the BU. The DMs present criteria for use in the design of various types of facilities under the cognizance of NAVFAC.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Films on various subjects that may be of interest are listed in the *United States Navy Film Catalog*, NAVAIR 10-1-777, published 1 July 1971. Copies may be ordered in accordance with the *Navy Stock List of Forms and Publications*, NAVSUP 2002. Supplements to the Film Catalog are distributed to catalog holders.

When selecting a film, note its date of issue listed in the film catalog. As you know, procedures sometimes change rapidly. Thus some films become obsolete rapidly. If a film is obsolete only in part, it may sometimes be shown effectively if before or during its showing you carefully point out to trainees the procedures that have changed. For this reason, if you are showing a film to train other personnel, take a look at it in advance if possible so that you may spot material that may have become obsolete and verify current procedures by looking them up in the appropriate sources before the formal showing.

CHAPTER 2

SUPERVISION

As a Builder First or Chief, you will have many responsibilities added to those which you have had at the second class level. The higher your pay grade, the more likely it will be that your main duties will consist of supervising rather than doing.

At the First and Chief levels, you not only must be able to meet your Builder quals, you must also be thoroughly familiar with the duties of the Builder NEC holders. As you probably know the NEC holder is an individual that has a special skill; therefore, you should be knowledgeable enough in his specialty to be able to explain or supervise his performance on the job. The possession of these skills and knowledges will help you in supervising Builders. There are other requirements you must meet, however, if you are to carry out your supervisory responsibilities effectively. You will need to know how to handle your men to get the most out of them; you must be able to plan jobs, make estimates, and set up programs to train your men; you must be able to foresee difficulties and to devise methods for overcoming them; you must be able to maintain records and reports; and you must be safety conscious, ensuring that your men observe all safety precautions applicable to their job.

In this chapter, we discuss some of the major responsibilities of the supervisor such as administering a company accident prevention program, training and developing subordinates, and maintaining records and reports. You must know this material to effectively handle your job as a supervisor.

SUPERVISION

The term supervision may be defined in a number of ways. As used in this chapter, it means overseeing, directing, and inspecting the work of others. Supervision, then, means working with people. To perform this duty it is extremely important, of course, for a supervisor to be technically competent in his specialty. However, there is a basic difference between a supervisor who is merely technically competent and one who knows how to get maximum production. The good supervisor is one who understands the job to be done and knows capabilities of his men and the techniques of good supervision.

SOME HINTS ON SUPERVISION

Supervision is probably more of an art than a science; the same techniques that work well in one situation may have little application to a different situation. Nevertheless, there are certain principles that will generally apply to any situation.

First, a supervisor should be able to ORGANIZE. This simply means that he should be able to analyze what requirements the project entails and plan the sequence of steps that will bring about desired results. Suppose you have to assign a crew of men to hang doors and install windows for a new building being constructed. You should be able to look at the job that has to be done and estimate how many manhours are required to complete it; you will probably have been given a date by which the work is to be completed. Next (or perhaps even before making your estimate of manhours), plan the sequence of operations. Make sure that you also know the answer to the following questions: What is the size of the windows and doors and how many are required? Is the material being shipped in, or being prepared at the activity? What tools are available, and what is their condition?

Before assigning work, give careful consideration to the qualifications of your men. Are they experienced Builders? Will any training be required before certain men can wedge and hang a door properly? Are any men scheduled for leave? Will you need to request additional men? After getting answers to these questions, you should be able to assign your men accordingly and set up tentative schedules. If shifts are necessary, make arrangement for the smooth transition from one shift to another with the minimum of work interruption. How well you are able to carry out these steps is directly related to your ability to organize.

In addition to organizing, you must be able to DELEGATE. This is one of the most important characteristics of a good supervisor. Failure to delegate is a common failing of a new supervisor. It is only natural to want to carry out the details of a job yourself, particularly when you know that you can do it better than any of your subordinates. Trying to do too much, however, is one of the quickest ways to get bogged down in details and to slow down a large operation. On some projects, you may have crews working in several different places. Obviously, you cannot be in two places at the same time. There will be many occasions when a crew member needs assistance or instruction on some problem that arises. If he has to wait until you are available, then valuable time will be lost. It is important, therefore, for you to delegate authority to one or more of your crew members to make decisions in certain matters. Here, knowledge of the men in your crew is an important factor. Some men can handle responsibility well; others cannot. You must know who can make sound decisions in your absence and who cannot. You must also remember that, although you are allowed to delegate authority, you are still responsible for the completion of the job.

The ability to COORDINATE operations is another important aspect of good supervision. When a number of operations are in progresss, it is important that they be planned so one can follow another without delay. Poor coordination is indicated if a glazier is kept waiting because there are not enough window frames available, or if a Builder installing locks has to wait because the door has not been put on the hinges beforehand. From these examples, you can see that supervision requires planning, coordinating, delegating, and organizing. So, as a good supervisor, remember to employ these techniques in your daily supervisory activities.

SUPERVISORY RESPONSIBILITIES

In effectively performing your supervisory activities, you must be in direct contact with, and have direct control over, the individuals who are engaged in the work of production. Therefore, to maintain and improve production you should bear in mind the following major duties and responsibilities of a supervisor.

1. Production.
2. Safety, health, and physical welfare of subordinates.
3. Development of cooperation.
4. Development of morale.
5. Training of subordinates.
6. Administrative Duties (Records, reports, job orders, etc.).

The aforementioned duties and responsibilities are to be looked at as the general aspects of supervision. A detailed list of the techniques involved in the accomplishment of these duties and responsibilities could be made only with regard to the supervision of a particular project. However, the following techniques have fairly general application:

1. Getting the right man on the job at the right time.
2. Maintaining quality and quantity of production.
3. Planning and encouraging teamwork.
4. Controlling attendance.
5. Keeping subordinates satisfied and happy on the job.
6. Maintaining discipline.
7. Settling differences among subordinates.
8. Adjusting grievances.
9. Maintaining good job houskeeping.
10. Keeping records and making reports.
11. Developing and maintaining cooperation with other crews.
12. Preparing and disseminating rules, organization charts, work procedures, and the like.

13. Planning and scheduling work.
14. Giving orders and directions.
15. Providing organized and unorganized training.
16. Requisitioning tools, shop equipment, and materials.
17. Using and placing materials economically.
18. Checking and inspecting materials.
19. Inspecting, caring for, and preserving tools and shop equipment.
20. Preventing accidents by safety training and control of hazards.

Of the six major supervisory duties and responsibilities, No. 4 (development of morale) is covered to a great extent in *Military Requirements for Petty Officer 3 & 2* and *Military Requirements for Petty Officer 1 & C*. Therefore, we will discuss the remaining five in this chapter.

PRODUCTION

The primary responsibility of every supervisor is PRODUCTION. Production can best be obtained in the following three ways:

1. By planning and organizing the work to get maximum production with minimum effort and confusion.
2. By delegating as much authority as possible, while remaining responsible for the final product.
3. By continuous supervision and control to ensure that the work is done properly.

SAFETY, HEALTH, AND PHYSICAL WELFARE OF SUBORDINATES

Safety and production go hand in hand, since the only efficient way to do anything is a safe way. When men are absent because of injury, shop equipment is down because of damage, or completed work is destroyed by accident, production will definitely fall Therefore, you as a supervisor must be a constant teacher of safety; you must set examples by constantly observing all safety precautions; you must teach safety as an integral part of each training unit; and you must plan each job with safety in mind.

Showing concern for the health and physical welfare of your subordinates will also pay off production-wise. Remember that a healthy worker in a state of good physical being is inherently a more efficient worker than one who does not enjoy this advantage. Besides, concern for these matters is bound to increase the favor with which the subordinates will view you and motivate them to additional efforts.

COOPERATION

The necessity for developing cooperation between the members of your crew is quite obvious when you are trying to improve production. However, some supervisors have a tendency to overlook the necessity for developing cooperation between the officers and enlisted supervisor of crews of other departments.

Cooperation among the members of your crew is best obtained by being a supervisor who is willing to tell his men the what and whys of their work. And another important thing that will develop cooperation among the men is continual training to prepare them for increased responsibilities and new skills.

It is essential that you cooperate with your seniors on the project and in the battalion, continually informing them of circumstances which (1) require their decisions or other actions, and (2) would be unknown to them unless you pass the word. It is often the case that what you (and perhaps your men as well) imagine to be the indifference of your seniors is actually a result of the fact that you have not kept them informed.

If you have ever had to chop a hole through a long-since-hardened reinforced concrete wall to admit a water pipe or electrical conduit, or had to dismantle part of an erected structure to accommodate plumbing or electrical installation, you know that cooperation with supervisors of other crews is of prime importance in the construction field. As you are aware, in structural work erected under the supervision of the Builders there must nearly always be openings left, or other provisions made, for the installation of plumbing and electrical features. In many cases, certain phases of the structural work must be postponed until plumbing or electrical features have been installed. Working drawings for Builders may show in general the nature of the provisions for plumbing and electrical installation. However, to get a clear picture of just what should be done and when, you as the Builder supervisor should have the advice of, and cooperate continually with, the plumbing and/or electrical supervisor.

Particularly important, too, is constant cooperation between you and the battalion's Field Engineering Section. This section is usually supervised by an Engineering Aid, and has, among other duties, that of establishing lines and grades for crews engaged in structural work. You will run into difficulty if you do not work with this section. Suppose, for example, you have forgotten to arrange for a stakeout of some phase of construction, but have a crew ready to start to work. You would then have to request a survey party to stakeout lines, but such a party cannot usually be provided immediately. The result would be idle time for your crew and a decline in production. If such were the case you would again have proof that cooperation on everyone's part is a must in the construction field.

TRAINING AND DEVELOPING SUBORDINATES

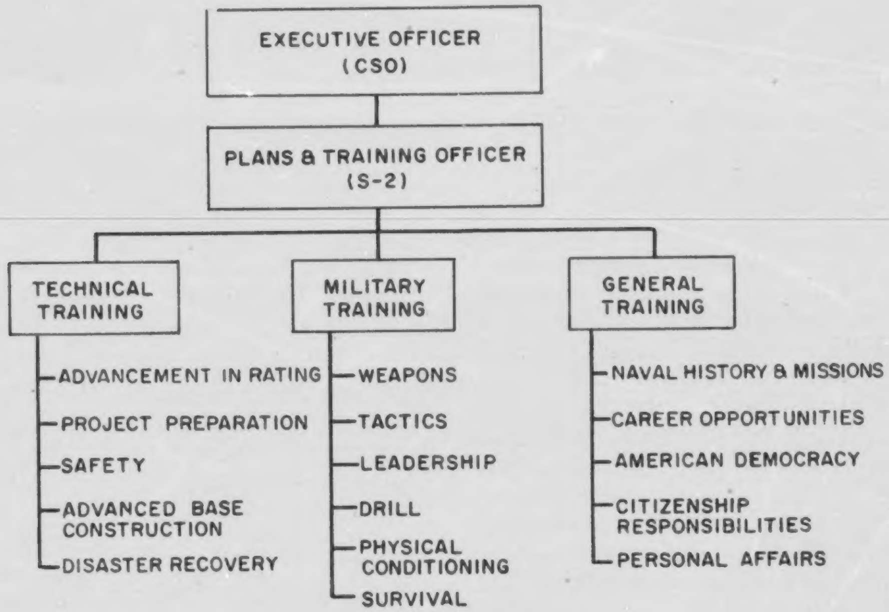
Each battalion's training program is formulated to provide personnel with the skills needed to accomplish the battalion's current and mobilization missions. The program is developed in accordance with the pattern, priorities, and tempo established by the commanding officer. It covers many phases from orientation courses to special technical courses. The success of a battalion training program depends upon such factors as operational commitments, policies, and directives from higher authorities; experience and previous training of the personnel; and training facilities available. Although much of the construction training will be provided by attending Class A, B, and C Schools as well as special SEABEE training courses, additional skill and experience must be acquired in the battalion.

Training Organization

Navy regulations state that the executive officer (CSO) will supervise and coordinate the work, exercises, training and education of personnel of the command. (See figure 2-1). The executive officer will supervise the training of battalion officers, coordinate the planning and execution of the training program and, when necessary, act to correct deficiencies in the program. He does this in his capacity as chief staff officer. His principal assistant is the plans and training officer (S-2).

Company commanders are directly responsible for the training of their company personnel and for the fulfillment of training goals established by the commanding officer. The company commanders will help formulate training programs; supervise training of subordinate officers; and direct technical military and general training of their companies. The battalion service department heads are responsible for the individual training of personnel in the departments. They conduct training for advancement and administer the OPNAV-sponsored general training. Platoon leaders observe closely the training progress of the men in their platoons. They directly supervise on-the-job constuction and military training. All petty officers assume the responsibility for training their men and must be able to conduct effective training courses utilizing lectures, discussions, project work, and so on.

The plans and training officer is generally assisted by a permanently assigned staff of three or four petty officers and by additional personnel on a part-time basis as necessitated by the battalion's formal training workload. This group is generally headed by a chief petty officer, and its members often function as training instructors. Although this group is responsible for the entire battalion training program, they are primarily concerned with the formulation and administration of the formal military training program and that part of the technical training program which includes advanced base construction and disaster recovery. The other aspects of the technical training and general training programs are formulated and administered within each company, but should correspond to the


EXECUTIVE OFFICER
(CSO)
PLANS & TRAINING OFFICER
(S-2)
TECHNICAL TRAINING
MILITARY TRAINING
GENERAL TRAINING
ADVANCEMENT IN RATING
PROJECT PREPARATION
SAFETY
ADVANCED BASE CONSTRUCTION
DISASTER RECOVERY
WEAPONS
TACTICS
LEADERSHIP
DRILL
PHYSICAL CONDITIONING
SURVIVAL
NAVAL HISTORY & MISSIONS
CAREER OPPORTUNITIES
AMERICAN DEMOCRACY
CITIZENSHIP RESPONSIBILITIES
PERSONAL AFFAIRS

143.133

Figure 2-1. –Battalion Training Organization Chart.

general guidelines established by the plans and training officer.

In the Amphibious Construction Battalion, the training officer may serve as assistant to the operations officer. He arranges and schedules all formal training of officers and enlisted men, performing essentially the same duties as the plans and training officer of the Naval Mobile Construction Battalion.

In general, training should be consistent with the following guidelines:

1. It must be closely integrated and coordinated with daily operations of the battalion. The plan and organization for training that is adopted must not interfere with essential construction functions.

2. Notwithstanding the guideline just listed, the construction schedule should be flexible so that opportunities for training that will expedite the construction schedule are not neglected.

3. Maximum advantage should be taken of the opportunity to derive training benefits from routine operations.

Training Needs

Training for advancement is a continuous factor concerning all personnel within a battalion, whether at the company or platoon level. As a supervisor, one of the many responsibilities of which you must be cognizant of is the keeping of practical factors for your crew members. A Record of Practical Factors, NavPers Form, 1414/1, is used for this purpose showing in which practical factors for the next higher rate on which a Builder has been checked out. The Builder will need training in those factors in which he has not been qualified. NavPers Form 1414/1 accompanies a man's service record when he is transferred, thus indicating to the new command those areas in which he must be examined. When a new man is assigned to your work crew, you will then be alerted to the additional training that he may need.

The battalion's next assignment will also provide clues as to needed training. If the next assignment is to be construction of a Butlerhut, there will undoubtedly be a great deal of prefabrication going on. You will need to see how many qualified Builders are available; you might need to train more men to interpret and work from blueprints. Or, if the next assignment is to place a finish concrete, you might have to train several men in finishing concerete. Your company commander, in consultation with the operations officer and training officer, can give you advice as to training needs based on the battalion's future operations.

A study of the skills required to do a particular job will be the starting point for training. After you have made this study, take inventory of the skills the men in your crew now possess. You can easily see whether the required skills match the available skills. If they do not match, this is a good indication that some training is needed to bring the men up to the desired level of proficiency. In some cases, you will need to conduct refresher training; in other cases, you will have to give instructions on new techniques.

As a supervisor, you may also check your crew's service records, conduct a PRCP interview, which will be explained later, and select those best suited for consideration of a more formal type training given at a Class A, B, or C School.

On-The-Job Training

On-the-job training will probably be your most common training responsibility. Therefore, it is essential that you be equipped to assume the responsibility of training your men on-the-job. On-the-job training plays a major role in the development of highly skilled Builders. There is no substitute for experience. Since overseas construction is subject to inspection and rigid scheduling, it makes sense to integrate scheduled technical training with on-the-job training. Preferably, the scheduled technical training should be given in field demonstrations of applied construction theory. Training of this type should be aimed at improving individual and crew proficiency and thereby obtaining higher quality workmanship. Improved quality will result in improved production since less corrective work will be required. When the desired level of proficiency has been reached, training should be directed at broadening individual and crew capabilities.

Insofar as practical, you should attempt to rotate your operations on the various jobs involved in normal construction operations so as to provide the crew members with the opportunity to broaden their individual capabilities. Training for your senior petty officers should include provisions for becoming familiar with the general aspects of the other construction ratings. (This is known as cross-rate training.)

In carrying out your training responsibilities, you must develop the ability to put yourself in the shoes of your subordinates—to see their needs and to understand their fears and tensions. The ability to do this will help you recognize the anxiety experienced by the new Builder as he stands for the first time in the work area facing him, new surroundings, and new fellow Builders. It will help to deliberately look at the job from the new Builder's viewpoint rather than always through the eyes of one with years of experience and familiarity with the operation.

Formal Training

Formal training is, in general, training that goes on outside of the normal working hours or during periods of enforced nonworking hours—for instance, inclement weather. Such training usually takes place during regularly scheduled training periods and is often conducted in groups. Participation may or may not be voluntary.

Formal training may be particularly useful when a number of men in your crew are scheduled to take a fleetwide examination for advancement. Here, the instructing petty officers conduct training in general subject matter areas, particularly knowledge factors. Formal training may also be used when a special operation is scheduled for the battalion, such as a trip to the arctic or the tropics. If the battalion is to engage in a new type of construction that requires special knowledge, this, too, might call for a formal training situation.

Formal training makes heavy use of the lecture and demonstration method of teaching. Before attempting to teach a group of men you would do well to restudy the training section in *Military Requirements for Petty Officer 3 & 2*, *Military Requirements for Petty Officer 1 & C*, and the *Manual for Navy Instructors.* These manuals will provide excellent information on how to direct and conduct training.

There is no "best" method for training that applies to every situation, but there are a number of pointers that will usually apply. For one thing, make sure your material is complete. Do not leave out any steps or significant information. Arrange your material in a systematic and orderly manner so that each step rests securely upon the information already provided. Avoid overlapping since too much repetition is a waste of time and usually leads to lack of attention on the part of the trainees.

Subject matter for formal training may be classified as knowledge type, attitude type, or skill type. Knowledge type subject matter is the type taught to build up a store of useful facts, principles, theories, and so on. Attitude-type subject matter is taught for the purpose of creating proper feelings, understandings, respect, and the like. Skill-type subject matter, mental or physical, is subject matter taught for the purpose of helping a man acquire an ability to perform required jobs with ease, speed, and precision.

Remember, no one man can do everything and the faster you see to it that your men are properly trained, the more effectively your crew will perform.

ADMINISTER A COMPANY ACCIDENT PREVENTION PROGRAM

Each command is required to establish a safety organization to develop, organize, and direct a comprehensive accident prevention program and to provide for the promulgation and enforcement of safety precautions and safe construction techniques. The safety program is usually under the direction of a SAFETY OFFICER designated by the commanding officer. The safety officer has the authority to take immediate steps to stop any operation where there is impending danger of injury to personnel or damage to equipment or material.

The safety officer lays out the safety program, after conducting job analyses and consultations with the supervisors in charge of the various phases of construction. He maintains an adequate safety library, provides and equips safety bulletin boards, and obtains and distributes safety educational materials like posters, pamphlets, films, books, and visual aids. He initiates and encourages activities designed to stimulate and maintain interest in safety. He coöperates with construction supervisors in the selection and placement of warning signs. He investigates and reports on all accidents, and makes recommendations with regard to the prevention of recurrences.

A chief petty officer may be designated as safety chief in an NMCB to assist the safety officer who usually has other collateral duties.

Safeguards and Safety Education

Many supervisors feel that it is only necessary to provide safeguards and safety will then take care of itself. Provision of safeguards is a move in the right direction, but it alone will not get good results. To maintain a good safety record, you as the supervisor need to employ a combination of safety devices and safety training. If each man has had sound safety training, he will be able to guard against even those hazards where safety devices are impracticable. You must, however, train every man in the use of safeguards, explaining why, as well as how, they should be used. How many times have you seen a man shut off the power on a machine and then walk away from it before it has stopped turning? Such a man uses a safeguard, but he does not know why he uses it. By providing the necessary training, you as an alert supervisor must make sure that such careless uses of safeguards do not happen again.

Standup safety meetings should be held in the shop once every week. The meetings should be held at or near the work area. Instead of a routine safety lecture, it is much better to hold a group discussion on specific accidents that are to be guarded against or that may have happened in the unit. The men should be encouraged to express their ideas. A group conclusion as to how specific accidents can be prevented should be reached.

Another type of safety meeting is one in which the supervisor presents a safety problem that has developed because of new work or new equipment. Again, the men should be invited to express their ideas.

A third type of safety meeting is one in which actual demonstrations and practice by the group are carried out. You might demonstrate how to lift, and then have the men practice lifting. Also, to make the reason for lifting in this manner more realistic, a little lesson on the classes of tools and a little problem in ratio and proportion should prove interesting.

If you are demonstrating how to use a saw, bring in a saw and use it—do not just talk about how to use it. Then, again, let the men practice.

Making these meetings interesting is of the utmost importance. The supervisor should not complain or scold, and the meetings should be limited in time. The subject matter should be thought out carefully in advance and it should be timely. Considerable ingenuity is required to keep these meetings from degenerating into dull routine affairs. Some supervisors have the men themselves rotate as leaders of the safety meetings—an excellent device to maintain interest. Hundreds of good motion pictures and other visual aids are available on safety subjects. Use them!

Safety Inspections

In order to do your part in the administration of the safety program, you must have a thorough knowledge of the safety precautions which apply to the various types and phases of construction, involving personnel and equipment. To perform in this supervisory inspection role you must carry out the safety recommendations of the safety officer. Listed below are some of the recommendations usually recommended by safety officers.

1. Promulgate and enforce all safety regulations.
2. Instruct and drill your men in safe practices.
3. Caution your men with regard to occupational hazards.
4. Inspect work areas regularly.
5. Do not assign men to jobs beyond their technical and physical capabilities.
6. Report any accidents.
7. Analyze all accidents, and recommend appropriate action to prevent recurrence.

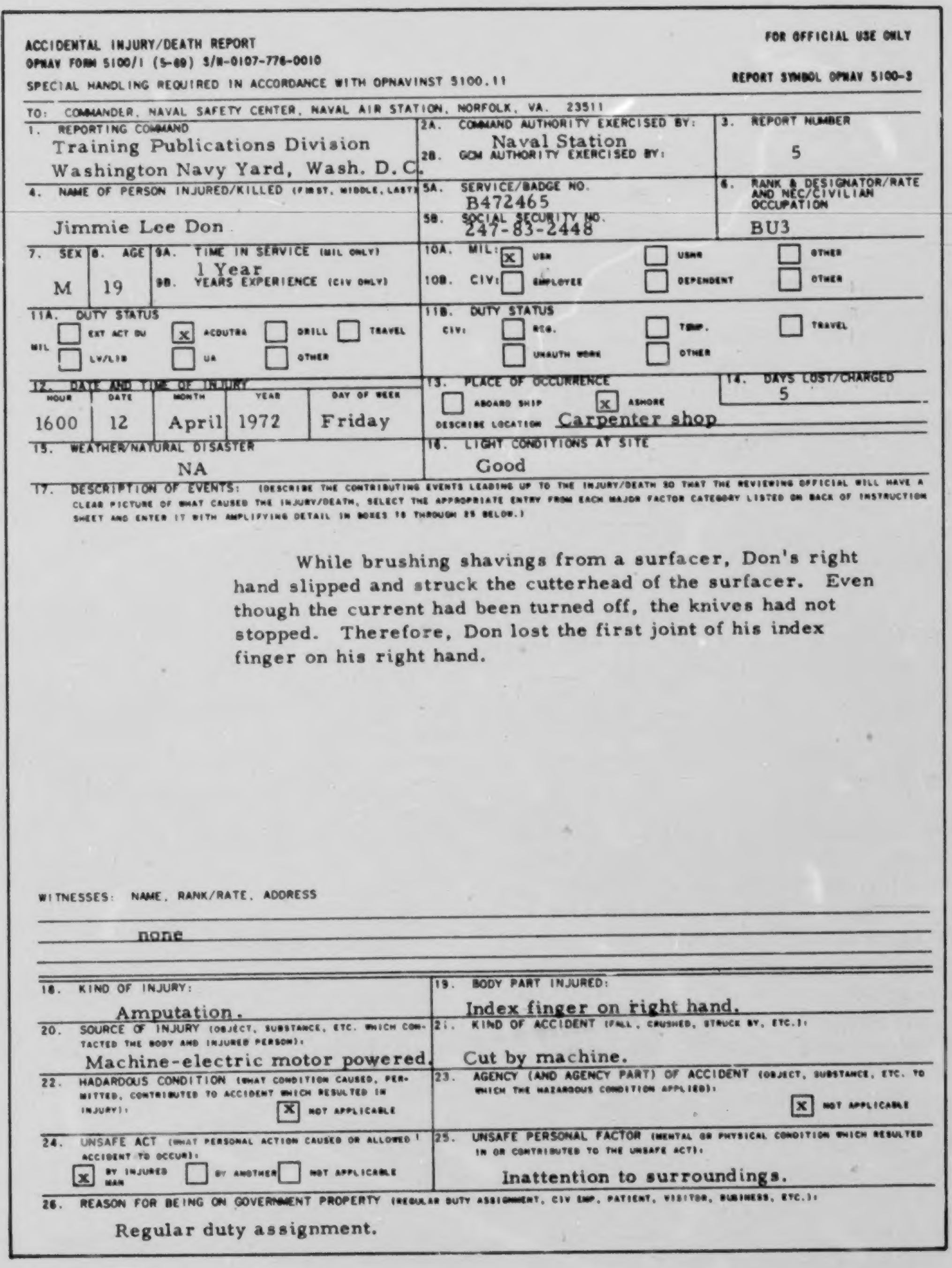
Accident Reporting

When an accident occurs in your shop, office, or within your crew, you must fill out an OpNav Form 5100/1 Accidental Injury/Death Reports. (See figures 2-2 through 2-5). This form provides a method of recording the essential facts concerning an accident, from which data for use in accident prevention can be compiled. Item 27—"Corrective action taken/recommended"—is the most important part of this report. The manner in which this question is answered provides a clue to the attitude of the supervisor. Too many supervisors answer this question with, "The man had been warned to be more careful." This type of answer does not mean a thing. The answer to this question should tie in with the rest of the report. If an unsafe working condition is the cause of the accident, you cannot correct it by warning the man to be more careful. Study the report; analyze it; then take the proper corrective action. This report is one of your best accident prevention tools if properly used. In many cases, the difference between a minor accident and a major one is a matter of luck. Do not ignore the small cuts and bruises; investigate the reasons for them and correct the causes. If you do this, you will have a safe shop or office and an efficient one.

Accident Investigation

To fill out the OpNav Form 5100/1 properly, as shown in figures 2-2 and 2-3, an accident investigation must be conducted. Here are six important factors you should consider:

1. Unsafe conditions. Was the equipment improperly guarded, unguarded, or inadequately guarded? Was the equipment or material rough, slippery, sharp-edged, decayed, worn, or cracked? Was there a hazardous arrangement, such as congested work space, lack of proper lifting equipment, or unsafe planning? Was there proper illumination and ventilation? Was the man dressed properly for the job? Was the man provided with proper respirator goggles/gloves?



ACCIDENTAL INJURY/DEATH REPORT
OPNAV FORM 5100/1 (5-69) S/N-0107-776-0010
SPECIAL HANDLING REQUIRED IN ACCORDANCE WITH OPNAVINST 5100.11

FOR OFFICIAL USE ONLY
REPORT SYMBOL OPNAV 5100-3

TO: COMMANDER, NAVAL SAFETY CENTER, NAVAL AIR STATION, NORFOLK, VA. 23511

1. REPORTING COMMAND: Training Publications Division Washington Navy Yard, Wash. D. C.
2A. COMMAND AUTHORITY EXERCISED BY: Naval Station
2B. GCM AUTHORITY EXERCISED BY:
3. REPORT NUMBER: 5
4. NAME OF PERSON INJURED/KILLED (FIRST, MIDDLE, LAST): Jimmie Lee Don
5A. SERVICE/BADGE NO.: B472465
5B. SOCIAL SECURITY NO.: 247-83-2448
6. RANK & DESIGNATOR/RATE AND NEC/CIVILIAN OCCUPATION: BU3
7. SEX: M
8. AGE: 19
9A. TIME IN SERVICE (MIL ONLY): 1 Year
9B. YEARS EXPERIENCE (CIV ONLY):
10A. MIL: ☒ USN ☐ USNR ☐ OTHER
10B. CIV: ☐ EMPLOYEE ☐ DEPENDENT ☐ OTHER
11A. DUTY STATUS MIL: ☐ EXT ACT DU ☒ ACDUTRA ☐ DRILL ☐ TRAVEL ☐ LV/LIB ☐ UA ☐ OTHER
11B. DUTY STATUS CIV: ☐ REG. ☐ TEMP. ☐ TRAVEL ☐ UNAUTH WORK ☐ OTHER

12. DATE AND TIME OF INJURY

HOUR	DATE	MONTH	YEAR	DAY OF WEEK
1600	12	April	1972	Friday

13. PLACE OF OCCURRENCE: ☐ ABOARD SHIP ☒ ASHORE
DESCRIBE LOCATION: Carpenter shop
14. DAYS LOST/CHARGED: 5
15. WEATHER/NATURAL DISASTER: NA
16. LIGHT CONDITIONS AT SITE: Good
17. DESCRIPTION OF EVENTS: (DESCRIBE THE CONTRIBUTING EVENTS LEADING UP TO THE INJURY/DEATH SO THAT THE REVIEWING OFFICIAL WILL HAVE A CLEAR PICTURE OF WHAT CAUSED THE INJURY/DEATH, SELECT THE APPROPRIATE ENTRY FROM EACH MAJOR FACTOR CATEGORY LISTED ON BACK OF INSTRUCTION SHEET AND ENTER IT WITH AMPLIFYING DETAIL IN BOXES 18 THROUGH 25 BELOW.)

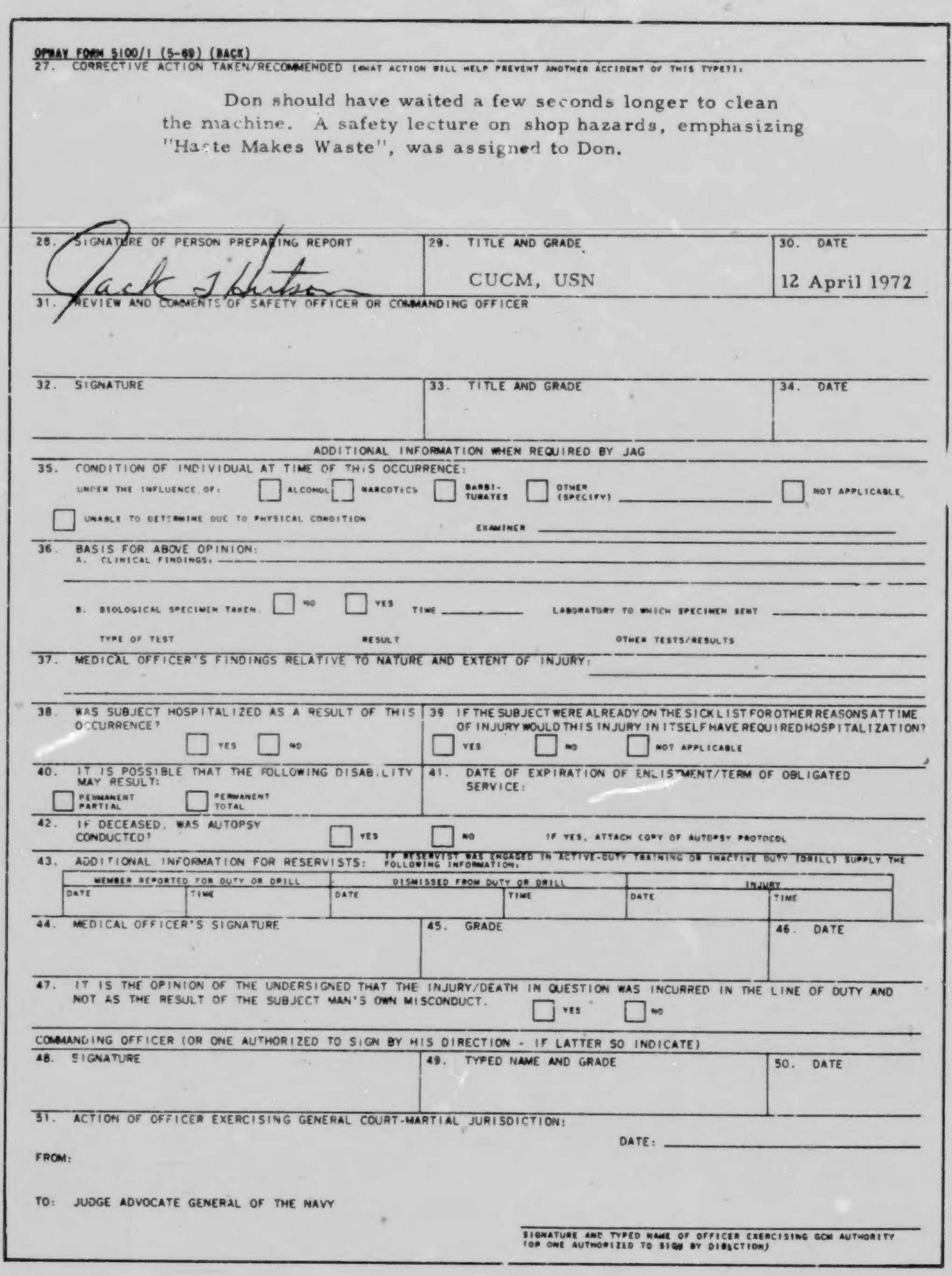
While brushing shavings from a surfacer, Don's right hand slipped and struck the cutterhead of the surfacer. Even though the current had been turned off, the knives had not stopped. Therefore, Don lost the first joint of his index finger on his right hand.

WITNESSES: NAME, RANK/RATE, ADDRESS
none

18. KIND OF INJURY: Amputation.
19. BODY PART INJURED: Index finger on right hand.
20. SOURCE OF INJURY (OBJECT, SUBSTANCE, ETC. WHICH CONTACTED THE BODY AND INJURED PERSON): Machine-electric motor powered.
21. KIND OF ACCIDENT (FALL, CRUSHED, STRUCK BY, ETC.): Cut by machine.
22. HADARDOUS CONDITION (WHAT CONDITION CAUSED, PERMITTED, CONTRIBUTED TO ACCIDENT WHICH RESULTED IN INJURY): ☒ NOT APPLICABLE
23. AGENCY (AND AGENCY PART) OF ACCIDENT (OBJECT, SUBSTANCE, ETC. TO WHICH THE HAZARDOUS CONDITION APPLIED): ☒ NOT APPLICABLE
24. UNSAFE ACT (WHAT PERSONAL ACTION CAUSED OR ALLOWED ACCIDENT TO OCCUR): ☒ BY INJURED MAN ☐ BY ANOTHER ☐ NOT APPLICABLE
25. UNSAFE PERSONAL FACTOR (MENTAL OR PHYSICAL CONDITION WHICH RESULTED IN OR CONTRIBUTED TO THE UNSAFE ACT): Inattention to surroundings.
26. REASON FOR BEING ON GOVERNMENT PROPERTY (REGULAR DUTY ASSIGNMENT, CIV EMP, PATIENT, VISITOR, BUSINESS, ETC.): Regular duty assignment.

29.52.1(2D)

Figure 2-2. –Accidental Injury/Death Report OpNav Form 5100/1 (front).



OPNAV FORM 5100/1 (5-69) (BACK)

27. CORRECTIVE ACTION TAKEN/RECOMMENDED (WHAT ACTION WILL HELP PREVENT ANOTHER ACCIDENT OF THIS TYPE?):

Don should have waited a few seconds longer to clean the machine. A safety lecture on shop hazards, emphasizing "Haste Makes Waste", was assigned to Don.

28. SIGNATURE OF PERSON PREPARING REPORT Jack T Hutson	29. TITLE AND GRADE CUCM, USN	30. DATE 12 April 1972

31. REVIEW AND COMMENTS OF SAFETY OFFICER OR COMMANDING OFFICER

32. SIGNATURE	33. TITLE AND GRADE	34. DATE

ADDITIONAL INFORMATION WHEN REQUIRED BY JAG

35. CONDITION OF INDIVIDUAL AT TIME OF THIS OCCURRENCE:

UNDER THE INFLUENCE OF: ☐ ALCOHOL ☐ NARCOTICS ☐ BARBITURATES ☐ OTHER (SPECIFY) ____________ ☐ NOT APPLICABLE

☐ UNABLE TO DETERMINE DUE TO PHYSICAL CONDITION

EXAMINER ____________

36. BASIS FOR ABOVE OPINION:

A. CLINICAL FINDINGS: ____________

B. BIOLOGICAL SPECIMEN TAKEN. ☐ NO ☐ YES TIME ________ LABORATORY TO WHICH SPECIMEN SENT ________

TYPE OF TEST RESULT OTHER TESTS/RESULTS

37. MEDICAL OFFICER'S FINDINGS RELATIVE TO NATURE AND EXTENT OF INJURY: ____________

38. WAS SUBJECT HOSPITALIZED AS A RESULT OF THIS OCCURRENCE? ☐ YES ☐ NO

39. IF THE SUBJECT WERE ALREADY ON THE SICK LIST FOR OTHER REASONS AT TIME OF INJURY WOULD THIS INJURY IN ITSELF HAVE REQUIRED HOSPITALIZATION? ☐ YES ☐ NO ☐ NOT APPLICABLE

40. IT IS POSSIBLE THAT THE FOLLOWING DISABILITY MAY RESULT: ☐ PERMANENT PARTIAL ☐ PERMANENT TOTAL

41. DATE OF EXPIRATION OF ENLISTMENT/TERM OF OBLIGATED SERVICE:

42. IF DECEASED, WAS AUTOPSY CONDUCTED? ☐ YES ☐ NO IF YES, ATTACH COPY OF AUTOPSY PROTOCOL

43. ADDITIONAL INFORMATION FOR RESERVISTS: IF RESERVIST WAS ENGAGED IN ACTIVE-DUTY TRAINING OR INACTIVE DUTY (DRILL) SUPPLY THE FOLLOWING INFORMATION:

MEMBER REPORTED FOR DUTY OR DRILL		DISMISSED FROM DUTY OR DRILL		INJURY	
DATE	TIME	DATE	TIME	DATE	TIME

44. MEDICAL OFFICER'S SIGNATURE	45. GRADE	46. DATE

47. IT IS THE OPINION OF THE UNDERSIGNED THAT THE INJURY/DEATH IN QUESTION WAS INCURRED IN THE LINE OF DUTY AND NOT AS THE RESULT OF THE SUBJECT MAN'S OWN MISCONDUCT. ☐ YES ☐ NO

COMMANDING OFFICER (OR ONE AUTHORIZED TO SIGN BY HIS DIRECTION - IF LATTER SO INDICATE)

48. SIGNATURE	49. TYPED NAME AND GRADE	50. DATE

51. ACTION OF OFFICER EXERCISING GENERAL COURT-MARTIAL JURISDICTION:

DATE: ____________

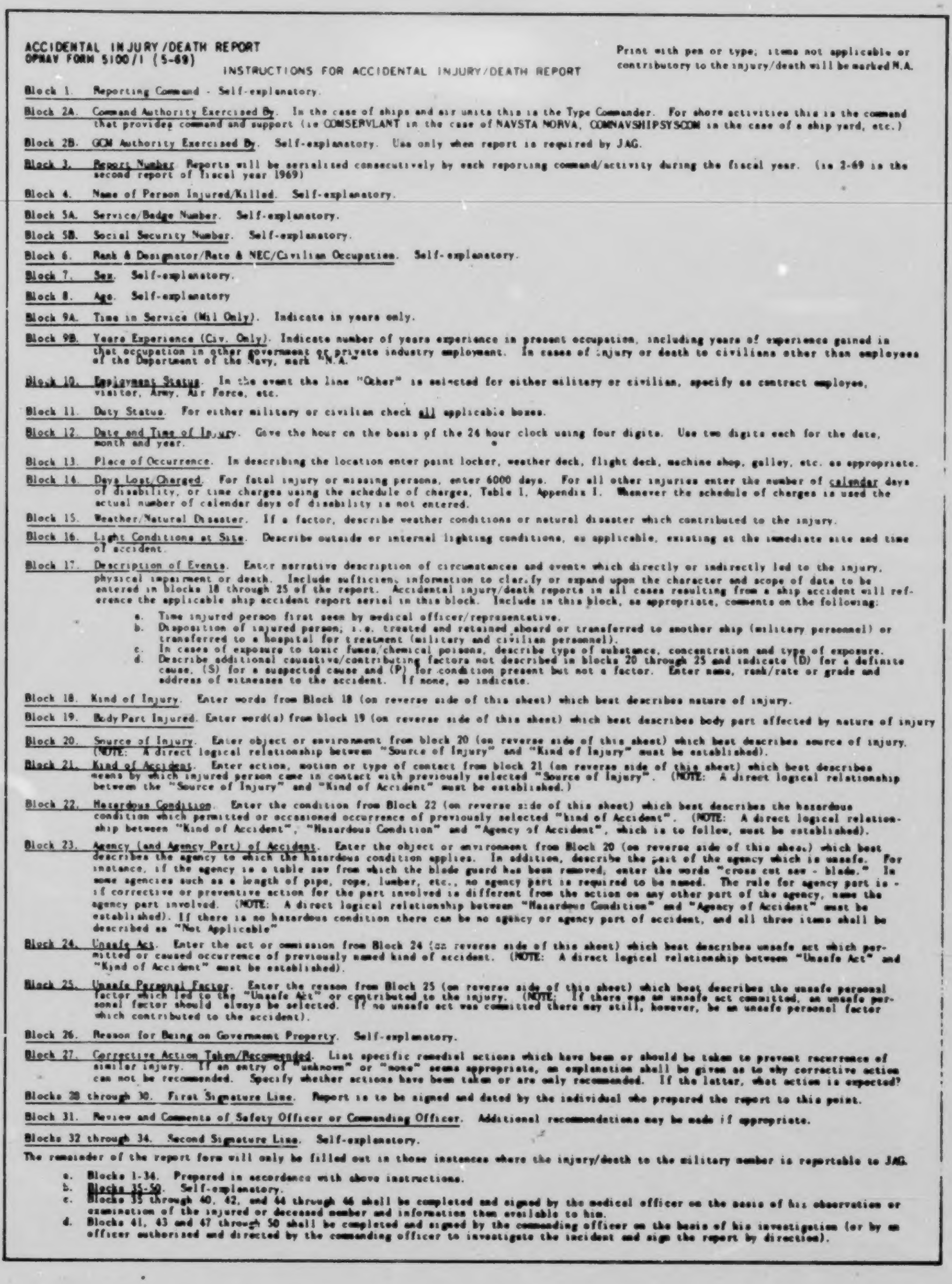
FROM:

TO: JUDGE ADVOCATE GENERAL OF THE NAVY

____
SIGNATURE AND TYPED NAME OF OFFICER EXERCISING GCM AUTHORITY (OR ONE AUTHORIZED TO SIGN BY DIRECTION)

29.52.2(2D)

Figure 2-3. —Accidental Injury/Death Report OpNav Form 5100/1 (back).



ACCIDENTAL INJURY/DEATH REPORT
OPNAV FORM 5100/1 (5-69)

Print with pen or type; items not applicable or contributory to the injury/death will be marked N.A.

INSTRUCTIONS FOR ACCIDENTAL INJURY/DEATH REPORT

Block 1. Reporting Command - Self-explanatory.

Block 2A. Command Authority Exercised By. In the case of ships and air units this is the Type Commander. For shore activities this is the command that provides command and support (ie COMSERVLANT in the case of NAVSTA NORVA, COMNAVSHIPSYSCOM in the case of a ship yard, etc.)

Block 2B. GCM Authority Exercised By. Self-explanatory. Use only when report is required by JAG.

Block 3. Report Number. Reports will be serialized consecutively by each reporting command/activity during the fiscal year. (ie 2-69 is the second report of fiscal year 1969)

Block 4. Name of Person Injured/Killed. Self-explanatory.

Block 5A. Service/Badge Number. Self-explanatory.

Block 5B. Social Security Number. Self-explanatory.

Block 6. Rank & Designator/Rate & NEC/Civilian Occupation. Self-explanatory.

Block 7. Sex. Self-explanatory.

Block 8. Age. Self-explanatory

Block 9A. Time in Service (Mil Only). Indicate in years only.

Block 9B. Years Experience (Civ. Only). Indicate number of years experience in present occupation, including years of experience gained in that occupation in other government or private industry employment. In cases of injury or death to civilians other than employees of the Department of the Navy, mark "N.A."

Block 10. Employment Status. In the event the line "Other" is selected for either military or civilian, specify as contract employee, visitor, Army, Air Force, etc.

Block 11. Duty Status. For either military or civilian check all applicable boxes.

Block 12. Date and Time of Injury. Give the hour on the basis of the 24 hour clock using four digits. Use two digits each for the date, month and year.

Block 13. Place of Occurrence. In describing the location enter paint locker, weather deck, flight deck, machine shop, galley, etc. as appropriate.

Block 14. Days Lost/Charged. For fatal injury or missing persons, enter 6000 days. For all other injuries enter the number of calendar days of disability, or time charges using the schedule of charges, Table 1, Appendix I. Whenever the schedule of charges is used the actual number of calendar days of disability is not entered.

Block 15. Weather/Natural Disaster. If a factor, describe weather conditions or natural disaster which contributed to the injury.

Block 16. Light Conditions at Site. Describe outside or internal lighting conditions, as applicable, existing at the immediate site and time of accident.

Block 17. Description of Events. Enter narrative description of circumstances and events which directly or indirectly led to the injury, physical impairment or death. Include sufficient information to clarify or expand upon the character and scope of data to be entered in blocks 18 through 25 of the report. Accidental injury/death reports in all cases resulting from a ship accident will reference the applicable ship accident report serial in this block. Include in this block, as appropriate, comments on the following:

- a. Time injured person first seen by medical officer/representative.
- b. Disposition of injured person; i.e. treated and retained aboard or transferred to another ship (military personnel) or transferred to a hospital for treatment (military and civilian personnel).
- c. In cases of exposure to toxic fumes/chemical poisons, describe type of substance, concentration and type of exposure.
- d. Describe additional causative/contributing factors not described in blocks 20 through 25 and indicate (D) for a definite cause, (S) for a suspected cause and (P) for condition present but not a factor. Enter name, rank/rate or grade and address of witnesses to the accident. If none, so indicate.

Block 18. Kind of Injury. Enter words from Block 18 (on reverse side of this sheet) which best describes nature of injury.

Block 19. Body Part Injured. Enter word(s) from block 19 (on reverse side of this sheet) which best describes body part affected by nature of injury

Block 20. Source of Injury. Enter object or environment from block 20 (on reverse side of this sheet) which best describes source of injury. (NOTE: A direct logical relationship between "Source of Injury" and "Kind of Injury" must be established).

Block 21. Kind of Accident. Enter action, motion or type of contact from block 21 (on reverse side of this sheet) which best describes means by which injured person came in contact with previously selected "Source of Injury". (NOTE: A direct logical relationship between the "Source of Injury" and "Kind of Accident" must be established.)

Block 22. Hazardous Condition. Enter the condition from Block 22 (on reverse side of this sheet) which best describes the hazardous condition which permitted or occasioned occurrence of previously selected "kind of Accident". (NOTE: A direct logical relationship between "Kind of Accident", "Hazardous Condition" and "Agency of Accident", which is to follow, must be established).

Block 23. Agency (and Agency Part) of Accident. Enter the object or environment from Block 20 (on reverse side of this sheet) which best describes the agency to which the hazardous condition applies. In addition, describe the part of the agency which is unsafe. For instance, if the agency is a table saw from which the blade guard has been removed, enter the words "cross cut saw - blade." In some agencies such as a length of pipe, rope, lumber, etc., no agency part is required to be named. The rule for agency part is - if corrective or preventive action for the part involved is different from the action on any other part of the agency, name the agency part involved. (NOTE: A direct logical relationship between "Hazardous Condition" and "Agency of Accident" must be established). If there is no hazardous condition there can be no agency or agency part of accident, and all three items shall be described as "Not Applicable"

Block 24. Unsafe Act. Enter the act or ommission from Block 24 (on reverse side of this sheet) which best describes unsafe act which permitted or caused occurrence of previously named kind of accident. (NOTE: A direct logical relationship between "Unsafe Act" and "Kind of Accident" must be established).

Block 25. Unsafe Personal Factor. Enter the reason from Block 25 (on reverse side of this sheet) which best describes the unsafe personal factor which led to the "Unsafe Act" or contributed to the injury. (NOTE: If there was an unsafe act committed, an unsafe personal factor should always be selected. If no unsafe act was committed there may still, however, be an unsafe personal factor which contributed to the accident).

Block 26. Reason for Being on Government Property. Self-explanatory.

Block 27. Corrective Action Taken/Recommended. List specific remedial actions which have been or should be taken to prevent recurrence of similar injury. If an entry of "unknown" or "none" seems appropriate, an explanation shall be given as to why corrective action can not be recommended. Specify whether actions have been taken or are only recommended. If the latter, what action is expected?

Blocks 28 through 30. First Signature Line. Report is to be signed and dated by the individual who prepared the report to this point.

Block 31. Review and Comments of Safety Officer or Commanding Officer. Additional recommendations may be made if appropriate.

Blocks 32 through 34. Second Signature Line. Self-explanatory.

The remainder of the report form will only be filled out in those instances where the injury/death to the military member is reportable to JAG.

- a. Blocks 1-34. Prepared in accordance with above instructions.
- b. Blocks 35-50. Self-explanatory.
- c. Blocks 35 through 40, 42, and 44 through 46 shall be completed and signed by the medical officer on the basis of his observation or examination of the injured or deceased member and information then available to him.
- d. Blocks 41, 43 and 47 through 50 shall be completed and signed by the commanding officer on the basis of his investigation (or by an officer authorized and directed by the commanding officer to investigate the incident and sign the report by direction).

29.52.3(127E)

Figure 2-4. —Instructions for Accidental Injury/Death Report (front).

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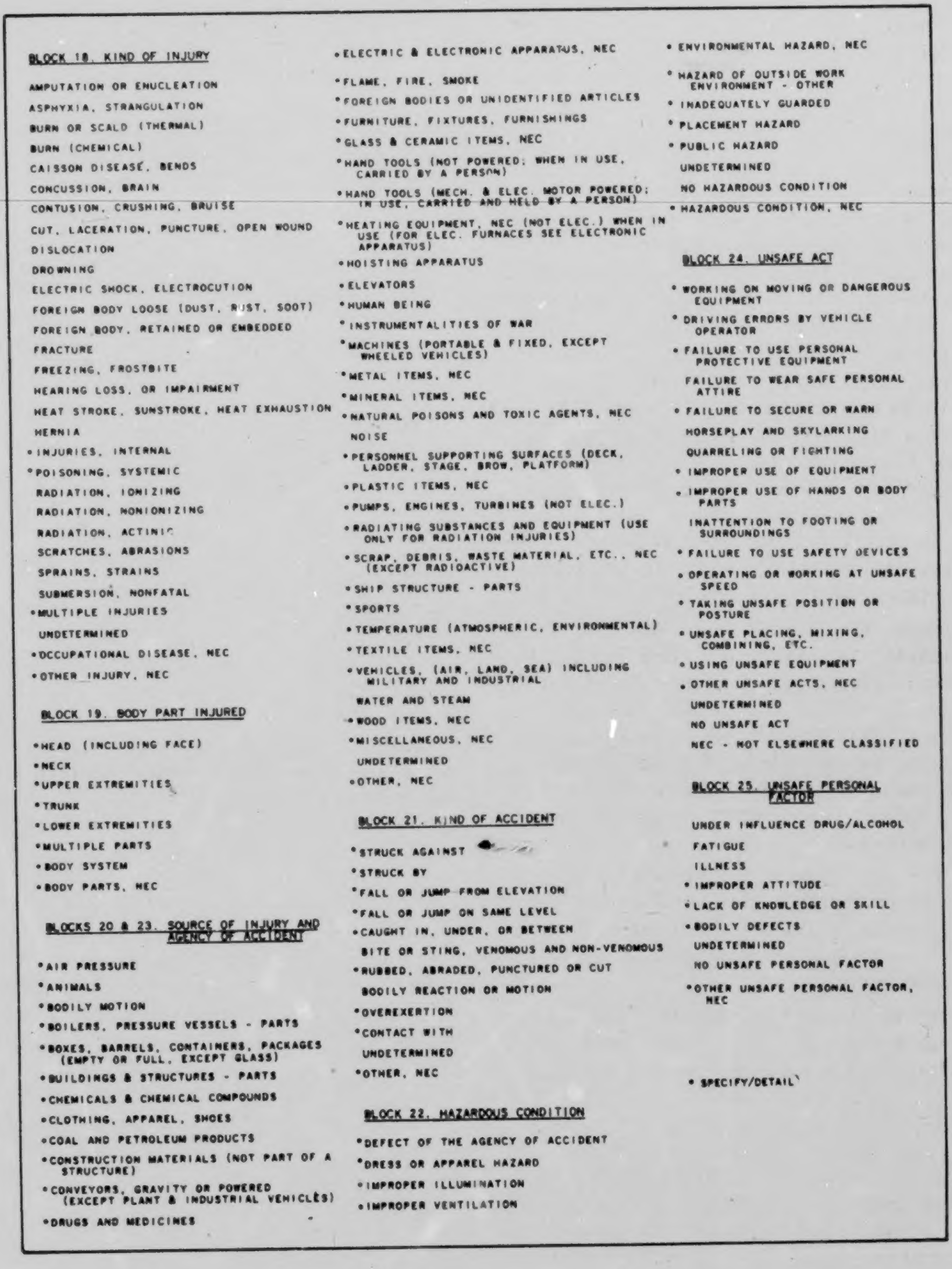


BLOCK 18. KIND OF INJURY

AMPUTATION OR ENUCLEATION
ASPHYXIA, STRANGULATION
BURN OR SCALD (THERMAL)
BURN (CHEMICAL)
CAISSON DISEASE, BENDS
CONCUSSION, BRAIN
CONTUSION, CRUSHING, BRUISE
CUT, LACERATION, PUNCTURE, OPEN WOUND
DISLOCATION
DROWNING
ELECTRIC SHOCK, ELECTROCUTION
FOREIGN BODY LOOSE (DUST, RUST, SOOT)
FOREIGN BODY, RETAINED OR EMBEDDED
FRACTURE
FREEZING, FROSTBITE
HEARING LOSS, OR IMPAIRMENT
HEAT STROKE, SUNSTROKE, HEAT EXHAUSTION
HERNIA
•INJURIES, INTERNAL
•POISONING, SYSTEMIC
RADIATION, IONIZING
RADIATION, NONIONIZING
RADIATION, ACTINIC
SCRATCHES, ABRASIONS
SPRAINS, STRAINS
SUBMERSION, NONFATAL
•MULTIPLE INJURIES
UNDETERMINED
•OCCUPATIONAL DISEASE, NEC
•OTHER INJURY, NEC

BLOCK 19. BODY PART INJURED

•HEAD (INCLUDING FACE)
•NECK
•UPPER EXTREMITIES
•TRUNK
•LOWER EXTREMITIES
•MULTIPLE PARTS
•BODY SYSTEM
•BODY PARTS, NEC

BLOCKS 20 & 23. SOURCE OF INJURY AND AGENCY OF ACCIDENT

•AIR PRESSURE
•ANIMALS
•BODILY MOTION
•BOILERS, PRESSURE VESSELS - PARTS
•BOXES, BARRELS, CONTAINERS, PACKAGES (EMPTY OR FULL, EXCEPT GLASS)
•BUILDINGS & STRUCTURES - PARTS
•CHEMICALS & CHEMICAL COMPOUNDS
•CLOTHING, APPAREL, SHOES
•COAL AND PETROLEUM PRODUCTS
•CONSTRUCTION MATERIALS (NOT PART OF A STRUCTURE)
•CONVEYORS, GRAVITY OR POWERED (EXCEPT PLANT & INDUSTRIAL VEHICLES)
•DRUGS AND MEDICINES
•ELECTRIC & ELECTRONIC APPARATUS, NEC
•FLAME, FIRE, SMOKE
•FOREIGN BODIES OR UNIDENTIFIED ARTICLES
•FURNITURE, FIXTURES, FURNISHINGS
•GLASS & CERAMIC ITEMS, NEC
•HAND TOOLS (NOT POWERED; WHEN IN USE, CARRIED BY A PERSON)
•HAND TOOLS (MECH. & ELEC. MOTOR POWERED; IN USE, CARRIED AND HELD BY A PERSON)
•HEATING EQUIPMENT, NEC (NOT ELEC.) WHEN IN USE (FOR ELEC. FURNACES SEE ELECTRONIC APPARATUS)
•HOISTING APPARATUS
•ELEVATORS
•HUMAN BEING
•INSTRUMENTALITIES OF WAR
•MACHINES (PORTABLE & FIXED, EXCEPT WHEELED VEHICLES)
•METAL ITEMS, NEC
•MINERAL ITEMS, NEC
•NATURAL POISONS AND TOXIC AGENTS, NEC
NOISE
•PERSONNEL SUPPORTING SURFACES (DECK, LADDER, STAGE, BROW, PLATFORM)
•PLASTIC ITEMS, NEC
•PUMPS, ENGINES, TURBINES (NOT ELEC.)
•RADIATING SUBSTANCES AND EQUIPMENT (USE ONLY FOR RADIATION INJURIES)
•SCRAP, DEBRIS, WASTE MATERIAL, ETC., NEC (EXCEPT RADIOACTIVE)
•SHIP STRUCTURE - PARTS
•SPORTS
•TEMPERATURE (ATMOSPHERIC, ENVIRONMENTAL)
•TEXTILE ITEMS, NEC
•VEHICLES, (AIR, LAND, SEA) INCLUDING MILITARY AND INDUSTRIAL
WATER AND STEAM
•WOOD ITEMS, NEC
•MISCELLANEOUS, NEC
UNDETERMINED
•OTHER, NEC

BLOCK 21. KIND OF ACCIDENT

•STRUCK AGAINST
•STRUCK BY
•FALL OR JUMP FROM ELEVATION
•FALL OR JUMP ON SAME LEVEL
•CAUGHT IN, UNDER, OR BETWEEN
BITE OR STING, VENOMOUS AND NON-VENOMOUS
•RUBBED, ABRADED, PUNCTURED OR CUT
BODILY REACTION OR MOTION
•OVEREXERTION
•CONTACT WITH
UNDETERMINED
•OTHER, NEC

BLOCK 22. HAZARDOUS CONDITION

•DEFECT OF THE AGENCY OF ACCIDENT
•DRESS OR APPAREL HAZARD
•IMPROPER ILLUMINATION
•IMPROPER VENTILATION
•ENVIRONMENTAL HAZARD, NEC
•HAZARD OF OUTSIDE WORK ENVIRONMENT - OTHER
•INADEQUATELY GUARDED
•PLACEMENT HAZARD
•PUBLIC HAZARD
UNDETERMINED
NO HAZARDOUS CONDITION
•HAZARDOUS CONDITION, NEC

BLOCK 24. UNSAFE ACT

•WORKING ON MOVING OR DANGEROUS EQUIPMENT
•DRIVING ERRORS BY VEHICLE OPERATOR
•FAILURE TO USE PERSONAL PROTECTIVE EQUIPMENT
FAILURE TO WEAR SAFE PERSONAL ATTIRE
•FAILURE TO SECURE OR WARN
HORSEPLAY AND SKYLARKING
QUARRELING OR FIGHTING
•IMPROPER USE OF EQUIPMENT
•IMPROPER USE OF HANDS OR BODY PARTS
INATTENTION TO FOOTING OR SURROUNDINGS
•FAILURE TO USE SAFETY DEVICES
•OPERATING OR WORKING AT UNSAFE SPEED
•TAKING UNSAFE POSITION OR POSTURE
•UNSAFE PLACING, MIXING, COMBINING, ETC.
•USING UNSAFE EQUIPMENT
•OTHER UNSAFE ACTS, NEC
UNDETERMINED
NO UNSAFE ACT
NEC - NOT ELSEWHERE CLASSIFIED

BLOCK 25. UNSAFE PERSONAL FACTOR

UNDER INFLUENCE DRUG/ALCOHOL
FATIGUE
ILLNESS
•IMPROPER ATTITUDE
•LACK OF KNOWLEDGE OR SKILL
•BODILY DEFECTS
UNDETERMINED
NO UNSAFE PERSONAL FACTOR
•OTHER UNSAFE PERSONAL FACTOR, NEC

• SPECIFY/DETAIL

29.52.4(127E)

Figure 2-5. —Instructions for Accidental Injury/Death Report (back).

2. Type of Accident. Was the man struck by some object? Did the man fall at the same level or to a different level? Was he caught in or between objects? Did he slip (not fall) or overexert himself?

3. Unsafe Act. Was the man operating a machine without proper authorization? Was he working at an unsafe speed, too fast or too slow? Was any safety device made inoperative (for example, blocked out or removed)? Was any load made unsafe or were tools or equipment put in an unsafe place where they would fall? Did someone fail to wipe up oil, water, grease, paint, etc., on working surfaces? Did the injured man take an unsafe position or posture? Did he lift with a bent back or while in an awkward position? Did he lift jerkily? Was he riding in an unsafe position on a vehicle? Was he using improper means ascending or descending? Was the injury caused by failure to wear the provided safe attire or personal protective devices such as goggles, gloves, masks, aprons, or safety shoes?

4. Unsafe Personal Factor. Was the man absent-minded or inattentive? Did he fail to understand instructions, regulations, and safety rules? Did he willfully disregard instructions or safety rules? Was he unaware of safe practices, unpracticed, or unskilled? Was he unable to recognize or appreciate the hazards? Did he have a bodily defect, such as poor eyesight, defective hearing, or hernia?

5. Type of Injury. Did he sustain a cut, bruise, sprain, strain, hernia, or fracture? Generally, you should get this information from a doctor, because it is often difficult for a layman to diagnose injuries.

6. Part of Body Affected. Did the injury involve arm, leg, ribs, feet, fingers, head, etc.? This information should also be obtained from the doctor.

The factors cited above will give you an idea of some of the things a supervisor must investigate and report when accidents occur. Each accident is different, and each should be investigated and judged on its own. Do not jump to conclusions. Start each investigation with an open mind. The most important factor in any accident investigation is to determine how to prevent a similar accident.

THE PERSONNEL READINESS CAPABILITY PROGRAM

The Personnel Readiness Capability Program (PRCP) is a management tool which was developed in the mid-1960's by the staff of the Commander, Construction Battalions, U.S. Atlantic Fleet and subsequently implemented throughout the active and reserve Naval Construction Force (NCF). The purpose of the PRCP is to increase the capabilities of the NCF in the areas of planning, decision making, and control by providing accurate and up-to-date personnel information to all levels of management.

Prior to the implementation of the PRCP, personnel information was kept on an "as required" basis by various members of the unit in personal notebooks, files, and records. As management required this information to determine military and construction capabilities, training requirements, logistics support, etc., it was collected. This collecting of information was usually a time-consuming, laborious task requiring a piecemeal inventory of the command's capabilities and/or requirements, or was obtained through the use of rough estimates. These methods, however, did not produce the accuracy or rapid response desired. Implementation of the PRCP helped solve these problems by establishing standard procedures for identifying, collecting, processing, and utilizing this needed information.

The Personnel Readiness Capability Program requires each participating command to gather, and continuously update, information on each member of their unit. Most of this information concerns skills acquired through actual job experience or through some type of training program. Other information, such as expiration of enlistment, rotation date, etc., is required for accurate planning. The gathering of this type of information is called SKILL INVENTORY.

SKILL INVENTORY

An accurate and current skill inventory is the "backbone" of the PRCP. Without it, the reliability of any planning based on information stored in the PRCP DATA BANK is questionable. Presently, all PRCP skills and other data are based on requirements established by COMCBPAC and COMCBLANT and promulgated in their joint instruction of the 1500.20 series. These skills have been conveniently classified into five major categories:

(1) *Individual General Skills.* These are essentially non-manipulative (knowledge) skills related to two or more ratings, such as Construction Inspection, Planning & Estimating, and Safety Inspection.

(2) *Individual Rating Skills.* This is the largest and perhaps most significant category. These skills are all primarily manipulative skills associated with one of the seven Group VIII (Construction) Ratings. Some examples are: Light Frame Construction for Builder, Cable Splicing for Construction Electrician, and Shore-Based Boiler Operation for Utilitiesman.

(3) *Individual Special Skills.* This category contains technical skills which are performed by several ratings, including non-Group VIII's. For example: Forklift Operation, Ham Radio Operation, and Typing.

(4) *Military Skills.* This is the second largest category. It is divided into two sub-categories: *General Military Requirements* and *Seabee Combat Readiness*. Respectively, examples are Disaster Recovery Training and Mines & Booby Traps.

(5) *Crew Experience (Skills).* This category comprises experiences gained by working with others on specific projects. Most of these projects are related to advanced base and heavy construction operations. Respectively, examples are the erection of advanced base field structures and pile driving.

To ensure the reliability of the PRCP, a book of skill definitions and a set of guides were developed so that the information, regardless of where it is collected or by whom, will provide NCF management with the information necessary for planning, decision making and control.

Skill Definitions

A book of standard SKILL DEFINITIONS, *Book 1 PRCP Skill Definitions*, has been prepared, which contains a definition for every skill identified in the Personnel Readiness Capability Program. These definitions have been jointly approved by COMCBLANT, COMCBPAC, and CNRT (Chief of Naval Reserve Training) and are applicable to the entire Naval Construction Force.

PRCP Interviewer's Standards and Guides

The skill definitions alone do not contain sufficiently detailed information to accurately classify people, nor do they provide any classification procedures. Recognizing this, special SEABEE workshops were conducted by the Seabee Support and Equipment Office (SSEO) and, under their guidance, the *PRCP Interviewer's Standards and Guides* were developed. These "Guides" contain a detailed TASK ANALYSIS of each skill definition as well as standard procedures for their use. The *PRCP Interviewer's Standards and Guides* are the principal tools used in collecting skill data. They can be used two ways: (1) By following the interviewing procedures in each guide, a trained interviewer is able to classify people to a predetermined skill level within an acceptable degree of uniformity; and (2) anyone so authorized can, by having a thorough knowledge of the tasks required of each skill, classify others to an appropriate skill level by actually observing the men perform the tasks, either in training or on the job.

Skill information obtained from interviewing or observing is submitted to the Facilities System Office (FACSO), Port Hueneme, California on a special form known as a TRANSCRIPT MASTER. This form, which consists of multiple sheets of carbon sensitive paper, is preprinted with every skill identified in the PRCP. Normally, it is only necessary to mark the appropriate skill levels attained, send a copy to FACSO—where the data bank is maintained—and retain a designated copy at the unit level. Complete instructions and information for using the Transcript Master, as well as other PRCP data processing information, can be obtained from the training officer of units participating in the program.

As a E-6 crew/squad leader, you are directly responsible for using the *PRCP Interviewer's Standards and Guides* to interview your men (or others) and to provide the initial information for the PRCP data bank. Subsequent UPDATING of this initial information will be based on your observance of the man performing on the job or upon his performance at a school. New men, however, and others returning from long periods of certain types of shore duty, may require interviews.

PRCP INTERVIEWS

There are two types of PRCP interviews. The first and most important is the INDIVIDUAL RATING SKILL INTERVIEW. The second type is simply called OTHER INTERVIEWS. Both types require the use of the *PRCP Interviewer's Standards and Guides.*

Rating Skill Interviews

The individual rating skill interviews require an experienced and knowledgeable tradesman. In these, a discussion technique is used by the interviewer to classify other SEABEES in the skill levels of the various individual rating skills. This technique requires a thorough understanding of the skills and tasks explained in the interviewing guides. It is recognized that few individuals possess the exceptional knowledge required to interview in all the skills of their rating. In this case, the interviewer must be mature enough to recognize his own limitations and be willing to seek assistance from others in his rating.

Other Interviews

The "other" interviews are used to classify people into the individual general and special skills, military skills, and crew experience. With only a few exceptions, these skills do not require an experienced interviewer; and in many cases, skill levels can be assigned without talking to the individual concerned by looking through the man's service or training record. Those skills requiring the man to be present can usually be assigned after a simple "Yes" or "No" answer. Administrative personnel, including company clerks, are ideal for conducting these "other" interviews.

USING THE INDIVIDUAL RATING SKILL GUIDES

When assigned as an interviewer, it is mandatory that you obtain, read, understand, and use the respective interviewing Guides. Each of the Guides is assembled in a standard format. First is a TITLE PAGE: this is followed by the SKILL DEFINITION: then comes the various TASKS which are broken down into several TASK ELEMENTS. (See figures 2-6, 2-7 and 2-8).

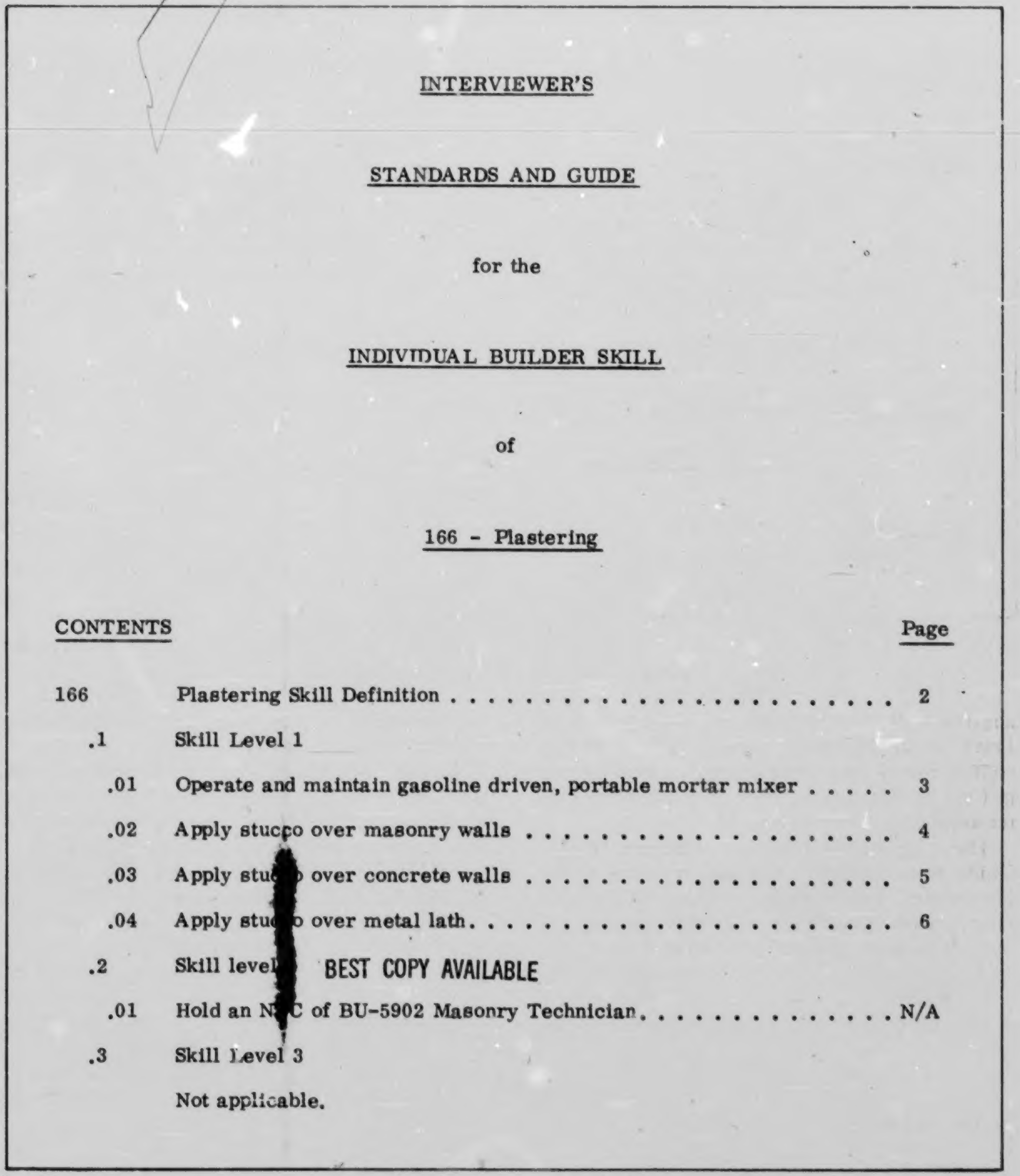
Title Page

The title page serves to identify the skill and the pages which follow. For example, the sample title page in figure 2-6 identifies the *Individual Builder Skill* of 166–Plastering. The number "166" is a numerical code which identifies this particular Builder skill. The CONTENTS can be used to ensure that there are no missing pages in your guide. The respective skill definition will always be listed first. Directly under this will be *.1 Skill Level 1.* Beneath each of the applicable skill levels are the "tasks" for which you must interview each candidate to see if he is qualified to that level.

Skill Definition

Figure 2-7 illustrates an individual rating skill definition. Its significant features are: a standard numerical designation and title (166–Plastering), a statement of tasks to be performed at each level, and the identification of training courses whereby the tasks may be learned.

Each skill definition consists of one, two, or three SKILL LEVELS, depending upon the complexity and number of the various TASKS which make up the skill. Each level within a given skill is more difficult to attain than the previous one; however, it has no relationship to



INTERVIEWER'S

STANDARDS AND GUIDE

for the

INDIVIDUAL BUILDER SKILL

of

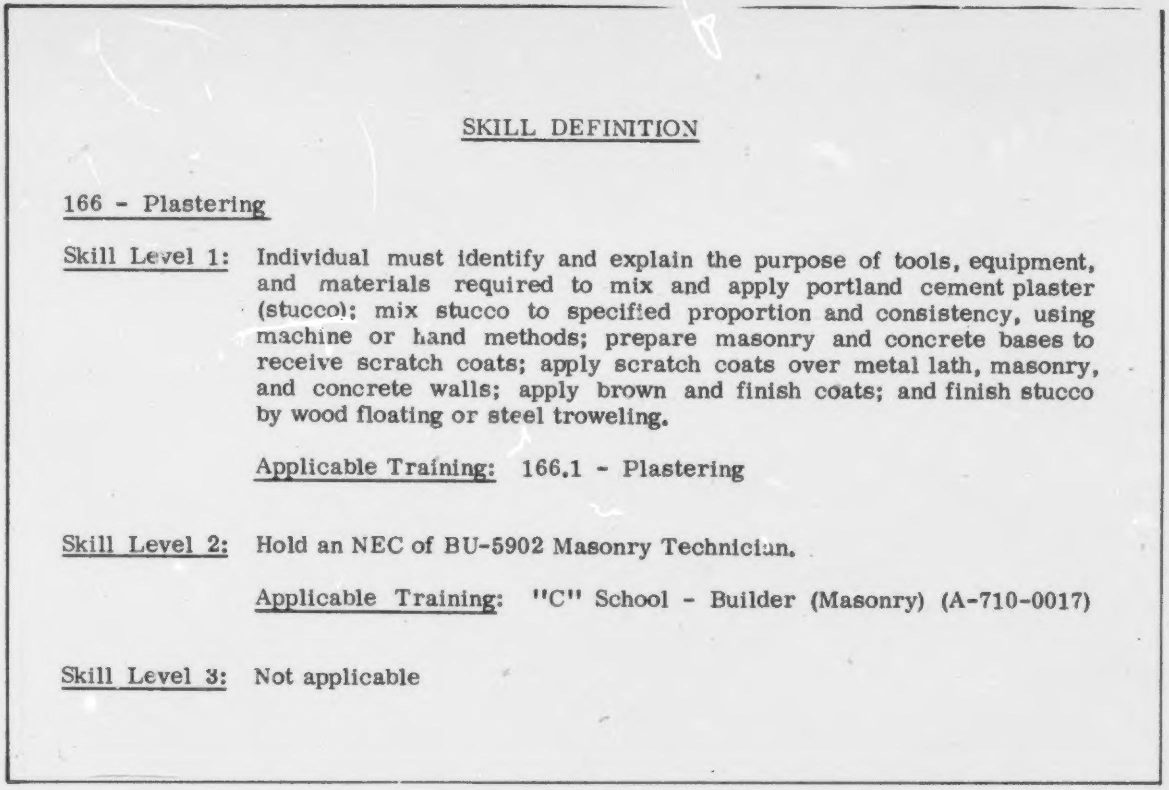
166 - Plastering

CONTENTS Page

166 Plastering Skill Definition 2
  .1 Skill Level 1
    .01 Operate and maintain gasoline driven, portable mortar mixer 3
    .02 Apply stucco over masonry walls 4
    .03 Apply stu[illegible] over concrete walls 5
    .04 Apply stu[illegible] over metal lath. 6
  .2 Skill level[illegible]
    .01 Hold an N[illegible]C of BU-5902 Masonry Technician. . . . . N/A
  .3 Skill Level 3
    Not applicable.

117.440

Figure 2-6. —Title page of the PRCP Interviewer's Standards and Guides.



SKILL DEFINITION

166 - Plastering

Skill Level 1: Individual must identify and explain the purpose of tools, equipment, and materials required to mix and apply portland cement plaster (stucco); mix stucco to specified proportion and consistency, using machine or hand methods; prepare masonry and concrete bases to receive scratch coats; apply scratch coats over metal lath, masonry, and concrete walls; apply brown and finish coats; and finish stucco by wood floating or steel troweling.

Applicable Training: 166.1 - Plastering

Skill Level 2: Hold an NEC of BU-5902 Masonry Technician.

Applicable Training: "C" School - Builder (Masonry) (A-710-0017)

Skill Level 3: Not applicable

117.441

Figure 2-7. —Individual Rating Skill Definition.

another skill. For example, a person with Skill Level 1 in Masonry Construction performs comparatively easy tasks, whereas a Skill Level 1 in Ceramic Tile Setting must perform everything required in that trade area.

The purpose of the skill definition in the Guide is to introduce the skill material to the interviewee. For example, you can begin your interview by reading the skill definition to the man. If he says he can do the related work, you may continue with the interview for that skill level; however, if he says he can't do the work, it is obvious that you should go on to some other skill.

Tasks and Task Elements

A task is a specific portion of the overall skill level. Many tasks cover relatively broad areas. Others may be quite specific and brief. Each task is further broken down into several smaller jobs called task elements.

A TASK ELEMENT is a basic part of each task. When interviewing, you will use the task elements and their related action statements to determine the interviewee's qualifications.

ACTION STATEMENTS tell you the type of information you should get from the man being interviewed. Each action statement is identified in the Guides by a capital letter (A, B, C, etc.). They are listed near the top and the number used varies from task to task. The first action statement in figure 2-8 is:

A. Describe the sequence of steps of this procedure and explain the reasons for each.

Note that each action statement is assigned a numerical VALUE. The value of each ranges from (1) to (5), depending on its relative

166.1.01 Operate and maintain gasoline driven, portable mortar mixer.

		VALUE
.00	For the TASK ELEMENTS listed below:	
	A. Describe the sequence of steps of this procedure and explain the reasons for each.	3
	B. List significant tools and equipment used in this procedure.	2
	C. Describe principal materials used in this procedure.	2
	D. Discuss the parameters of this procedure.	2
	E. Explain results if this procedure is NOT performed properly or it is neglected.	4
	F. Discuss safety precautions to be observed.	3
	G. Perform the steps of this procedure when practical.	5

	TASK ELEMENTS:	A	B	C	D	E	F	G	TOTAL
.01	Perform pre-start check.	3				4			7
.02	Fuel and lubricate.	3		2					5
.03	Start engine.	3					3		6
.04	Adjust operating speed.	3			2				5
.05	Secure engine.	3					3		6
.06	Perform operator's maintenance.	3	2	2		4			11
	a. Cleaning.	3		2					5
.07	Operate under actual conditions.							5	5
							Possible		50
							Qualifying		36

117.442

Figure 2-8. —Typical task analysis with task elements and related action statements.

importance to the discussion it will produce during the interview. The TOTAL value of all action statements applied to a particular task is called the POSSIBLE (score) and the total required to qualify an interviewee is called the QUALIFYING (score).

STEPS FOR INTERVIEWING

When interviewing, the first thing you should do is to attempt to put the interviewee at ease. A good way of doing this is by explaining the purpose of the interview. For example, the interview will:

a. Let the man know what he is actually expected to know and to do.

b. Determine what the man can actually do so that he is assigned to the right job.

c. Determine the man's deficiencies so that he will be programmed to receive proper training.

Next, explain to the interviewee that he should discuss what he knows of the skill honestly and that he should not be embarrassed if he doesn't know every item covered in the Guides.

Tell the interviewee what skill and skill level he's being interviewed for. Read the skill definition, as was suggested previously, to see if the man is knowledgeable of the subject.

Many skill levels require that the man hold a specific NEC (Navy Enlisted Classification). For example in figure 2-7, *Skill Level 2* of *Plastering* requires the individual to have an NEC of *BU-5902 Masonry Technician*. If the man has such an NEC, he should immediately be assigned the applicable skill level without being interviewed for any lower skill level.

Task Interviewing

Begin interviewing by reading the task. This helps the man to concentrate in the right area. This should be rephrased:

"The first thing we will discuss in *Plastering* is the operation and maintenance of the gasoline driven, portable mortar mixer."

Then read the first TASK ELEMENT (.01 Perform prestart check). By applying it through ACTION STATEMENT "A" (Describe the sequence of steps of this procedure and explain the reasons for each), it would sound something like this:

"Describe the sequence of steps when performing a pre-start check (on the mixer) and explain the reason for each step."

As you can see, this is not a question. It is a statement which tells the man that you want him to tell you what he knows about performing the steps of the pre-start check and the reasons for performing them. There are no questions in the *PRCP Interviewer's Standards and Guides*: therefore, no answers are provided. The Guides point out the areas to be discussed (in terms of TASK ELEMENTS and ACTION STATEMENTS), and the interviewee's replies are evaluated by the interviewer on the basis of his own personal experience, knowledge, and judgment.

It should be obvious now why all rating skill interviewers MUST be experienced in the skill for which they will interview. The only way you can determine that the interviewee knows the task element is to thoroughly know it yourself. If you are unfamiliar with, or "rusty" in, any tasks in the Guides, you must study these areas thoroughly before attempting to interview anyone. Also, if you do not understand how a particular action statement is used with a task element, you must resolve this before interviewing. Discuss the problem with others who are familiar with the skill.

ONLY discuss the task element with the action statements indicated in the columns to their right by the numerical value. For example in figure 2-8, only action statements "A" and "E" are used with task elements .01. And, in task element .05, only action statements "A" and "F" are applied. As an expert in the skill, you will probably have a desire to "ask questions" in tasks not covered by the Guides. This must be avoided as then there will be no standard. If you feel strongly that the guides can be improved, discuss your recommendation with the PRCP coordinator.

Scoring Interviews

If the interviewee discusses the task element to your satisfaction, he is awarded the numerical value of the applicable action statement. The interviewee is not awarded any partial values. He either knows that part of the task element–to which the action statement is applied–or he does not know it.

Continue to discuss all the task elements and action statements with the interviewee where indicated and award values for those you judge he is qualifed in. When a task is completed, total up the values awarded and, if they exceed or are equal to the qualifying score, certify the man as qualified. The same procedure is followed for the remaining tasks at that level.

A man must qualify in each task of a given skill level in order to qualify for that level. Once a man has been assigned a Skill Level 1, he may then be interviewed for Skill Level 2, and so on.

The scores, as such, are only used to determine whether or not the man is qualified to a given level and only the actual level received is entered on the TRANSCRIPT MASTER mentioned earlier.

Scoring should be done as the interview proceeds, and the man should be told how he is doing. If time permits, go over weak points with him and recommend how he can improve his technique or knowledge. A record of the interview provides a good basis for local training programs. For example, if several of your men don't know, or they have forgotten, the pre-start check procedure on the mortar mixer, you can set up a short training session to teach them on the actual equipment.

CHECKING OUT PRACTICAL FACTORS

Before any member of your crew can take the service wide examination for advancement, there must be an entry in his service record to show that he has qualifed in the practical factors of both the military qualifications and the occupational qualifications. A form known as the RECORD OF PRACTICAL FACTORS, NavPers 1414/1, as mentioned previously, is used to record the satisfactory completion of the practical factors, both military and occupational, listed in the *Quals Manual*. Whenever a crew member demonstrates his ability to perform a practical factor, appropriate entries should be made in the DATE and INITIALS columns.

As a BU1 or BUC, you may often be required to check the practical factor performance of lower rated men and to report the results to your supervising officer. If you had actually observed a man on a job doing precisely what the qualifications call for, you would have no reluctance in certifying that he has demonstrated his ability. On the other hand, the work situation may never offer an opportunity for a man to demonstrate his ability to perform a particular factor by actual performance. Fortunately, there is at least one way you can partially solve this problem. It will call for some effort on your part. You can develop some practical factor tests of your own. There may be defects, of course, in what you set up, because there is no entirely satisfactory substitute for the real thing.

Using practical factor tests for all practical factors in which a man must be checked out may require a considerable amount of time and effort, but this is one way you can fulfill your responsibilities as an instructor-supervisor. You will, of course, have to discuss your proposals for conducting practical factor tests with your company commander and with others in the battalion who have responsibility for the administration of the training program.

Now, for instance, suppose you have to check a man out in the practical factor "Administer a company accident prevention program" and you have not had the opportunity to observe the man performing this practical factor. One example of a self-made practical factor test for checking out the man in this practical factor is as follows:

A. OBJECTIVE:
To test the trainee's ability to organize and direct an accident prevention program for construction projects.

B. ESTIMATED TIME FOR TEST: 1 hour

C. MATERIALS:
1. INSTRUCTION 5100.1B COMCBLANT Safety Manual
2. NAVMAT P-5100–Department of the Navy Safety Precautions for Shore Activities

D. DIRECTIONS TO THE TRAINEE
1. Familiarize yourself with all safety precautions pertaining to construction projects
2. Talk to no one other than the supervisor during this test

E. DIRECTIONS TO THE SUPERVISOR
1. Assign the trainee as safety chief
2. Give the test in conjunction with other tests
3. Test each trainee separately

F. TEST
Did the trainee so organize and direct the accident prevention program in the various areas so that the following precautions were observed:

	PASSED	FAILED
1. SHOP		
a. Shields in place	______	______
b. Goggles, safety shoes, other safety devices used	______	______
c. Loose clothing, ties, and other clothing hazards corrected	______	______

	PASSED	FAILED
d. Tools properly secured and shop cleaned	______	______
2. ON THE JOB		
a. Ladders and scaffolds of prescribed type and strength	______	______
b. Proper safety devices (hard hats, gloves, etc.) used	______	______
c. Lumber and other materials properly stacked or stowed	______	______
d. Job site cleaned	______	______
3. PORTABLE ELECTRIC TOOLS		
a. Worn or frayed electric cords repaired or replaced	______	______
b. Tools properly used	______	______
c. All electric tools properly grounded	______	______
d. Electric tools not used if worker is standing in water or on damp ground	______	______
4. TRANSPORTATION		
a. Trucks properly loaded and loads secured	______	______
b. Riders prohibited except in the cabs or places provided for passengers	______	______
c. Flagman posted for backing	______	______
d. Speed regulated to driving conditions	______	______
5. GENERAL		
a. Fire hazards eliminated or kept at a minimum	______	______
b. Proper safety warnings given to crewmen	______	______
c. Safety stressed at all times	______	______
Grade		

Your grade, per segment of the test, will vary according to the practical factor and the emphasis that you think should be placed on each item. If the trainee observes all the precautions above, to your satisfaction, then he should be qualified in that particular practical factor.

ADMINISTRATIVE DUTIES

As you advance in rating, you can expect your job to require an increased amount of paperwork. If you have to spend a great deal of time doing paperwork, you may want to assign an assistant to handle part of it; however, you will be responsible for seeing that the work is done right. Keeping all your records and reports up-to-date will enable you to keep a close check on each job, each crew member and each piece of equipment under your supervision. Records and reports provide a means of checking the accomplished job progress as against the planned job progress. They also serve to summarize the experience gained on the present project, and become highly valuable aids in the planning and scheduling of future projects.

Your activity will have standard forms and blanks for keeping some of the required records and for making certain supply transactions; for example, job orders, work requests, and requisitions. In addition to these standard forms, various forms used for records and reports often are designed locally, and such forms may differ from one activity to another. At most activities you may find it advantageous to maintain logs, notebooks, charts, and so on, of your own design to meet your own specific needs. Some of the common types of records and reports that you may have to design as a supervisor are discussed below.

A WORK PROGRESS LOG is a record of all current and completed work accomplished by your shop and by each man assigned to the shop. You may design your own work progress log or it may be supplied by your activity; in any event, it should contain at least the following information for each job:

1. The job order number.
2. The date the job order was received.
3. The name of the unit requesting the job.
4. A brief description of the job.
5. The names of the men assigned to work on the job.
6. The total number of man-hours required to complete the job.

A JOB ORDER PROGRESS RECORD SHEET is a recording sheet used for presenting the status of all work currently being performed in the shop. At some activities a progress record sheet is made up at the close of each working day and submitted to the division office; a similar type of record sheet may be designed and submitted to show progress achieved on projects in the field. On the job order progress record sheet, all uncompleted job orders are listed by numbers; a brief description of each job should also be given, together with the date the job order was received. A chart should be provided to indicate the percentage of work completed on each job.

A MATERIAL EXPENDED RECORD is a very useful record for keeping track of the status of materials. (However, it might be noted that a record of this kind is utterly worthless unless it is faithfully maintained.) This record can best be kept in a notebook, with a separate section of the notebook being used for each type of material your shop uses. The information on a material expended record should include the date the material is received, the amount of material received, the date material is expended, the amount of material expended, the job order on which the material is used, and the balance of the material remaining on hand.

It is advisable that you as a shop supervisor also keep an EQUIPMENT LOG, listing all portable tools for which you are responsible and where these tools are located—whether in the shop, storeroom, toolroom, or assigned to an individual. An equipment log, kept up to date, with adequate tool descriptions—make, model, and serial number—will be of great assistance to you in making periodic inventories.

COMCBPAC has general forms that will serve in most situations: however, when you are assigned to CONUS/overseas shore duty and public works billets you may have to design and submit a DAILY MAN-HOUR REPORT. This report must include the work performed by the reporting unit and, when applicable, work performed by civilian labor, including indigenous and military personnel of other activities. In making this daily man-hour report you should also include labor expenditures. Labor expenditures should be included to provide management with data necessary to determine labor expenditures on project work for calculations of statistical labor costs, and comparison of actual construction performance with estimating standards. It will also aid in determining the effectiveness of labor utilization in performing administrative and support functions, both for internal unit management, and for development of planning standards by higher command.

As stated previously, each activity will more than likely come up with its own creation of a form for recording and reporting work situations; so no matter what type of form you use, fill it out properly, and submit when due.

CHAPTER 3

PLANNING, ESTIMATING, AND SCHEDULING

The Builder supervisor can expect planning, estimating, and scheduling to be involved with his job to some extent during almost every working day. This chapter provides information on planning that will be useful to you in planning jobs to be done in the shop or field. We will take up various types of estimates that may concern you in your work. We will explain the purpose of specific types of estimates and the different entries on these estimates. We will explain some of the basic factors to consider when scheduling the sequence of projects on a deployment, or the sequence of operations on a project. Topics covered included types of schedules, techniques of scheduling, and methods of progress control. Special attention is given in this instruction to the Critical Path Method (CPM) of scheduling. Basic fundamentals of CPM are discussed, and the method of constructing a CPM diagram is explained. From experience you may have learned that CPM is a valuable management tool when it comes to planning, scheduling, and controlling construction operations. To be a good planner and estimator, the Builder must know and understand technical drawings. As part of this instruction, information is provided on both technical drawings and technical sketching.

DRAWINGS AND SPECIFICATIONS

The process of construction usually begins with a concept which for the time exists only in the mind of the architect, designer, or other person who conceived it. Before the concept can become an actuality, all its significant details must be made readily and accurately available to the supervisors, foremen, and construction workers who will plan, supervise, and carry out the actual work of construction. These details could be made available in a variety of ways; experience has shown, however, that the most convenient, expeditious, and accurate method is through the use of TECHNICAL DRAWINGS supplemented by WRITTEN SPECIFICATIONS.

TECHNICAL DRAWINGS

As a Builder supervisor, it is important that you have a thorough knowledge of technical drawings. You will find this knowledge useful in estimating materials and labor, in scheduling, and in job planning. Accurate estimating requires a thorough examination of the drawings. All notes and references should be read carefully and all detail and reference drawings should be examined. Dimensions shown on drawings and/or figured dimensions should be used in preference to scaled dimensions. If it becomes necessary to scale dimensions on drawings, a scale rule should be used and the graphic scale on the drawings should be checked for expansion or shrinkage. When there is disagreement between the plans, elevations, and details, the detail drawing should normally be followed unless it is obviously wrong. Since much of the work that is done by Builders is indicated on technical drawings, you should clearly understand the drawings yourself, and be able to assist your subordinates in reading and working from them. In certain situations—such as the absence of drawings or to explain a part of a drawing—you may also have to prepare sketches for your men to follow.

A technical drawing is, simply, any drawing whose principal purpose is to show technical information as against a drawing whose principal purpose is decorative or illustrative. A technical drawing could show an object as it actually appears to the human eye; this type of 3-dimensional drawing is called DIMINISHING PERSPECTIVE. In figure 3-1 (1) an oblong box is shown in diminishing perspective. Actually, the front and rear upper edges of this box are of equal length. In the perspective drawing the line which represents the front edge, is longer than the line which represents the rear edge. Also, receding lines which are parallel to each other on the object itself appear to be converging toward each other in the perspective drawing. In figure 3-1 (1) receding lines are converging toward a single VANISHING POINT; this type of drawing is called ONE-POINT perspective. In figure 3-1 (2) receding lines are converging toward two vanishing points; this is known as TWO-POINT perspective.

Single Plane Projection

In a technical drawing, points and lines on the object are presumed to be PROJECTED onto a flat plane called the PLANE OF PROJECTION. A drawing of the types shown in figure 3-1 (1&2) is called a SINGLE-PLANE projection, because it presents a 3-dimensional view of the object on a single plane.

Single-plane projections have been devised in which the diminishing-with-distance distortion of the prespective drawing is to a large extent eliminated.

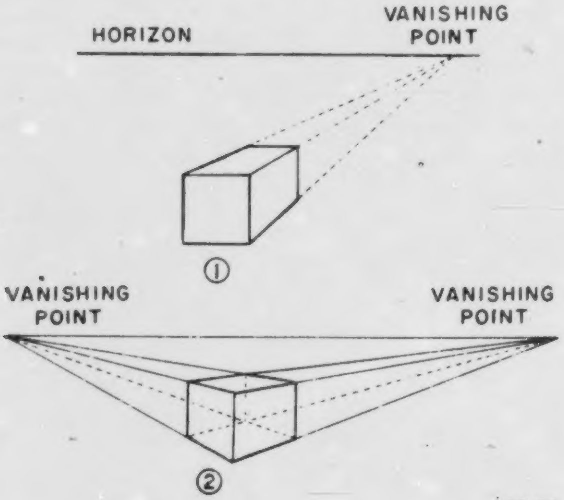


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Figure 3-1. —Perspective drawings.

ISOMETRIC PROJECTION.–The most commonly used of these projections is the ISOMETRIC projection. Figure 3-2 shows an isometric projection of a cubical block. The block is presumed to be so placed and tilted as to cause each of its surfaces to form an angle with the plane of projection. With the block so placed, each of the edge-lines, as it projects onto the plane, is shorter than the original line on the object by exactly the same proportion. In a technically correct isometric projection this foreshortening is calculated and deducted from the object dimensions by the draftsman making the projection. However, since the scale of reduction is the same for all lines, the foreshortening may be ignored, and the dimensions made equal to those on the object (with reduction, of course, to the scale of the drawing for a less-than-full-scale drawing). This type of isometric representation, in which the foreshortening of lines is ignored, is called an isometric DRAWING rather than an isometric projection.

In an isometric drawing, all ISOMETRIC lines appear in their true dimensions (as reduced or enlarged, of course, in a drawing not made to full scale). An isometric line is a line on the object which forms the isometric angle with the plane of projection. All of the lines visible in figure 3-2 are isometric lines; therefore, in an

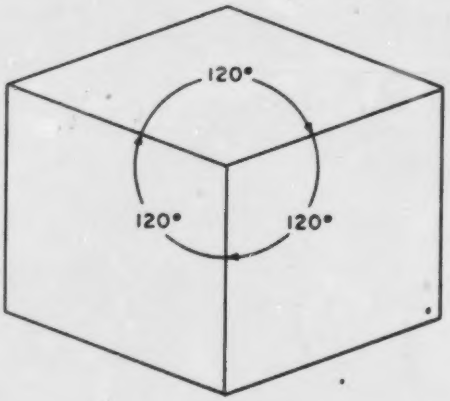

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Figure 3-2. —Isometric projection.

isometric drawing they would all appear in their true dimensions. However, a diagonal line (for example) drawn on the upper face of the block between two opposite corners would be a NONISOMETRIC line, and this one would NOT appear in its true dimensions on the drawing.

An isometric projection or drawing is constructed on the ISOMETRIC AXIS indicated by the 120-degree angles shown in figure 3-2. Any isometric line in the drawing is, as you can see, parallel to one or another of the three legs of the axis. For a nonisometric line you locate the end-points of the line by measurement along isometric lines, and then connect the end-points.

CAVALIER PROJECTION.–In isometric projection the LINES OF PROJECTION (that is, the imaginary lines which project points and lines from the object to the plane of projection) are presumed to be perpendicular (at right angles to) the plane of projection. In CAVALIER projection the lines of projection are presumed to make a 45-degree angle with the plane of projection.

In figure 3-2 (isometric projection) there is, as you can see, no face of the block that is parallel to the plane of projection. Instead, all faces make the isometric angle with the plane of projection.

Figure 3-3 shows the same block in cavalier projection. Here the front face of the block is presumed to be parallel to the plane of projection. Because the projectors are presumed to form a 45-degree angle with the plane of projection, the top and one side of the block are visible as well as the face. Again, all the visible lines appear in their true dimensions. Any NORMAL line on a cavalier projection, like any isometric line on an isometric drawing, will appear in its true dimensions. A normal line is one which is parallel to one or another of the legs in the cavalier axis. As shown in figure 3-3, the cavalier axis has two legs at right angles to each other and a third at any convenient angle to one of the other two. The third leg is known as the RECEDING axis.

All of the lines shown in figure 3-3 are normal lines; therefore, since the figure represented is a cube, they are all of the same length, appearing as they do in their true dimensions. Again, a diagonal line drawn between corners on the top face would be a NONNORMAL line (not parallel to any leg of the axis), and would not appear in its true dimensions.

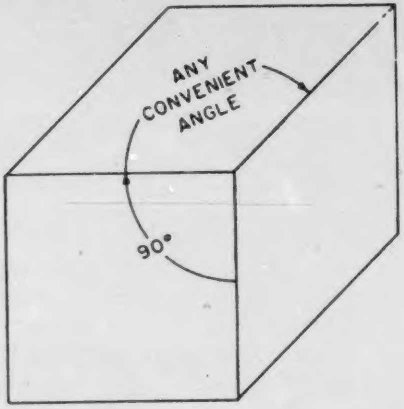

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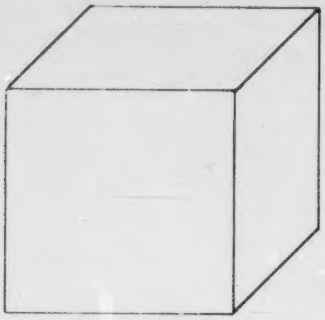
Figure 3-3. –Cavalier projection.

CABINET PROJECTION.–You can see that the block in figure 3-3 doesn't resemble a cube; the depth dimension looks longer than the height and width dimensions. This is because of the fact that the cavalier projection corrects the eye's diminishing optical illusion, and the eye is used to this illusion. To make a cavalier projection look more "natural", the receding axis is sometimes drawn to one-half of the scale of the other two axes. A projection of this kind is called a CABINET projection. The block shown in figures 3-2 and 3-3 is shown in cabinet projection in figure 3-4. You can see that the eye is better satisfied that this figure is a cube, but this appearance of "naturalness" is obtained by introducing a considerable error into the drawing (dimensions along the receding axis are one-half of the true dimensions).

Orthographic Multiview Projection

A projection in which the projectors are presumed to form a right angle with the plane of projection is an ORTHOGRAPHIC projection. One in which the projectors form an OBLIQUE (other than right) angle with the plane of



45.229

Figure 3-4. —Cabinet projection.

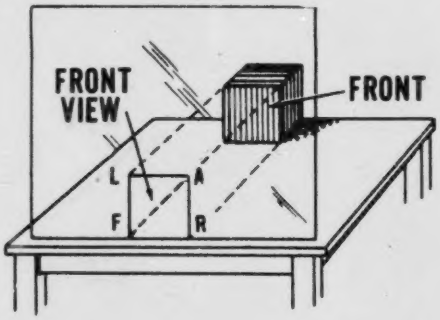
projection is an OBLIQUE projection. Therefore, an isometric projection is an orthographic projection, but cavalier and cabinet projections are oblique projections.

Now, on an isometric or cavalier projection all isometric or normal lines appear in their true dimensions, and lines which are parallel to each other on the object are likewise parallel to each other on the projection. Therefore, these projections are free of much of the distortion which appears in a perspective drawing. Nevertheless, both the isometric and the cavalier projection contain significant distortions. If you examine the figures which show these projections, you will see that all of the angles in an isometric projection and many of those in a cavalier projection are distorted. In an isometric projection all corner lines which join at a right angle on the cube itself join at oblique angles on the projection. The same is true of the cavalier projection, with the exception of corner angles relating to the front face of the cube.

On the cavalier projection the front face of the cube is represented with complete accuracy in that not only the front face dimensions, but likewise the front face corner angles, are true. The reason is the fact that in the cavalier projection the front face of the cube is presumed to be parallel to the plane of projection. It follows, then, that to show all surfaces of the cube with complete accuracy would require a separate plane of projection for each surface of the cube-meaning that a MULTI-PLANE, rather than a single-plane, projection would have to be used.

A cavalier projection is an oblique projection. But to show all surfaces of the cube accurately by multiplane projection, orthographic projection (in which the projectors are presumed to form a right angle with the plane of projection) is more convenient and more accurate than oblique projection. Therefore, orthographic multiplane (more commonly called MULTI-VIEW) projection is the most widely used method of presenting technical information in graphic form.

The principle of orthographic multiview projection is illustrated in figures 3-5, 3-6, and 3-7. Bottom, back, and left side views would be similarly projected. Figure 3-8 illustrates the method commonly used in the arrangement of the views. In the upper part of this figure there is an isometric drawing of an oblong block.



117.1

Figure 3-5. —Front elevation in an orthographic projection.

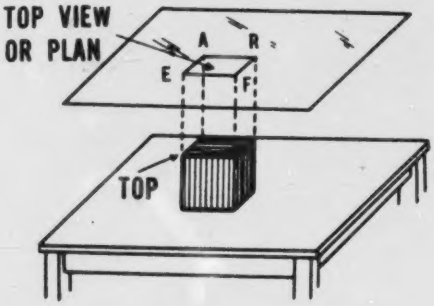


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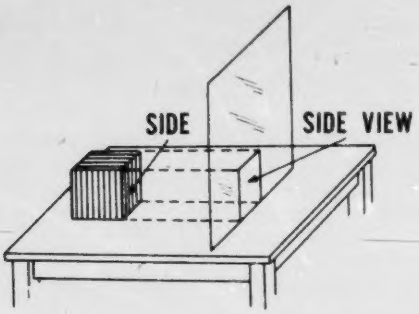
Figure 3-6. —Plan view in an orthographic projection.



117.3

Figure 3-7. –Side elevation in an orthographic projection.

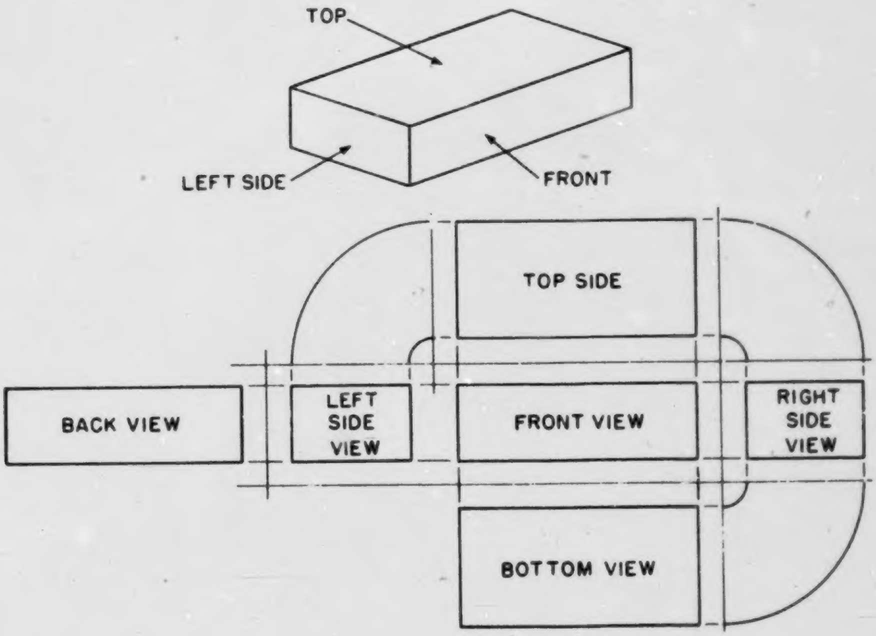
Below, there is a multiview orthographic projection which shows all six faces of the block, there being a separate view for each face.

Note that in the multiview orthographic projection both the dimensions and the angles are true, while in the isometric projection the dimensions are true but the angles are not. Multiview orthographic projection, then, is the method of technical drawing by which an object can be depicted with the most complete accuracy. Isometric projection, on the other hand, gives you a better idea of the general appearance of the whole object in a single view.

TECHNICAL SKETCHING

A technical drawing is made for the purpose of conveying technical information. It follows from this that a technical drawing contains only the graphic presentation required to show the required technical information completely. Consider figure 3-8, for example. In this figure the orthographic multiview projection shows six views of the block. It so happens, however, that all significant information about the block could be shown in three views (say, front, top, and right side), or even in only two (say, front and top). Therefore more than three, or more than two, views would be superfluous.

In one sense of the term, a MECHANICAL drawing means a floor plan which shows the utility system on a particular floor of a structure. In another sense of the term, however,



117.4

Figure 3-8. –Isometric and multiview orthographic projection.

mechanical drawing means NONFREEHAND drawing—that is, drawing in which all straight lines are made with the help of a straightedge, circles with the help of a compass, noncircular curves with the help of a french, ship, or railroad curve, and so on. The opposite of this type of mechanical drawing is FREEHAND drawing, in which lines, circles, and curves are drawn freehand.

Freehand technical drawing is called TECHNICAL SKETCHING. Basically, it is only the freehand character of a technical sketch that distinguishes the sketch from the more formal type of technical mechanical drawing made by a draftsman. The sketch, like the formal drawing, must show accurately all the technical information required for actual construction of the structure. Formal technical drawings are, in fact, often made by draftsmen from technical sketches prepared by design engineers.

The first consideration in planning a technical sketch is: What is the essential technical information which the sketch must convey? Obviously, for a structure, all significant dimensions are of prime importance. Significant dimensions include not only the lengths, heights, and thicknesses of walls, but also all dimensions required to locate such features as doors, windows, floors, and partitions.

The next consideration in planning a technical sketch is: What will the structural arrangements be—that is, what structural members will be required, what will their dimensions be, and how will they be arranged?

Suppose, for example, that you want to make a technical sketch of the formwork for an 8-in. thick concrete foundation wall 30 ft long by 5 ft high. What size studs will you use, and how far apart? What size wales, if any, and how far apart? What size bracing, and how many braces? Methods of determining these values are described in chapter 4.

How far down must you scale your sketch to make it fit your paper conveniently? Suppose your sketch paper is the common size of 8 in. by 10-1/2 in. The longest dimension for your formwork is 30 ft. Suppose you let 1/2 in. equal a foot. Then 30 ft will measure 15 in. to scale, which is too long for your paper. However, if you let 1/4 in. equal a foot, 30 ft will measure only 7-1/2 in. to scale, which is convenient enough for your paper. But in this case the 5 ft of height will scale down to only 1-1/4 in. on the paper—rather small for showing structural details.

But do you really need to show formwork for the whole wall in your sketch? Isn't it necessary to represent only enough of the formwork to show all significant structural details—a sketch containing, say, 5 or 6 studs? Suppose you have determined that studs must be spaced 16 in. O.C. To show a sketch containing 6 studs, you need show only a little over 6 ft 8 in. of wall. If you let 1/2 in. equal 1 ft, your wall length will scale down to about 3-1/3 in. and the height to 2-1/2 in. If you let 3/4 in. equal 1 ft, your scale length and height will be 5 in. and 3-3/4 inch. Either of these scales will fit your paper.

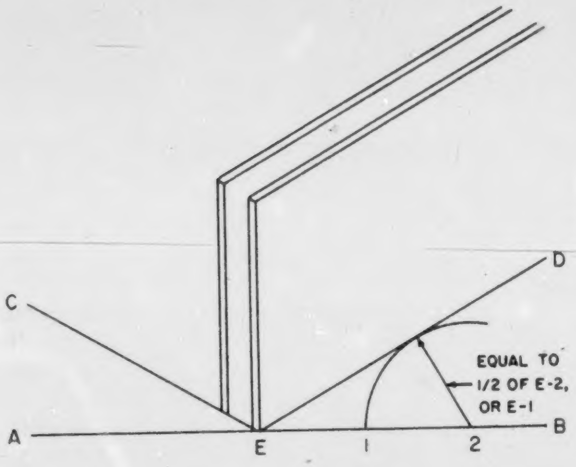
It's a good idea at this point to take a piece of scratch paper and write down all the significant dimensions for your sketch. In this case these dimensions are:

Length of wall to be shown	6 ft 8 in.
Height of wall	5 ft
Thickness of wall	8 in.
2 x 4 stud spacing	16 in. O.C.

You will use, then, either the 1/2 or 3/4 in. to the foot scale on your architect's scale to scale these dimensions on the sketch.

For sketching this section of formwork, an isometric drawing would seem to be the best idea. Start by sketching the isometric axis as shown in figure 3-9. Draw the horizontal line AB, and from E draw EC and ED at 30° to AB. If you do not have a protractor, you may get a 30-degree angle by laying off two equal units along EB, and striking an arc with a radius of one of the equal units laid off along EB. Then draw ED tangent to the arc as shown in figure 3-9.

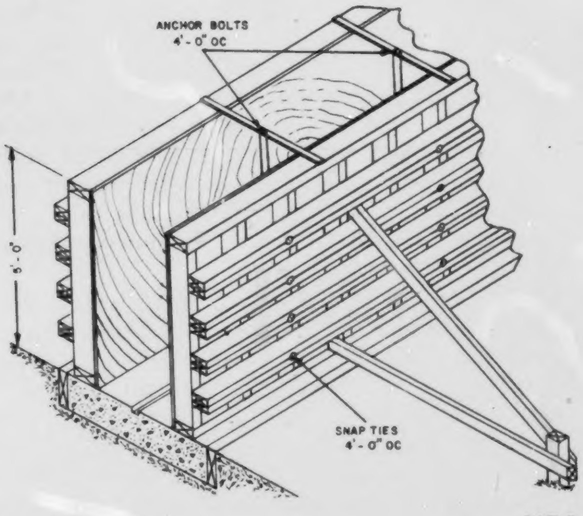
Proceed now to line in the rest of the sketch, as shown in figure 3-10. For the techniques of sketching, see the chapter entitled "Technical Sketching" in *Blueprint Reading and Sketching*, NavPers 10077-C. Although sketching is, by definition, freehand drawing, it is of course not essential that you draw all your lines freehand. If circumstances permit the use of a straightedge, you will find the drawing of straight lines much ea



117.5

Figure 3-9.—Constructing isometric axis.

Note that in figure 3-10, only essential information needed for actual construction is included. Only a single pair of stud braces is shown, for example, although additional braces are stipulated. Since additional sketches of braces would convey no information not available in a single sketch, the additional sketches are left out. On this basis it would not, in fact, have been necessary to show more than a single pair of studs and a single wale.



117.6

Figure 3-10. —Technical sketch of wall formwork.

WRITTEN SPECIFICATIONS

Drawings are supplemented by WRITTEN SPECIFICATIONS, commonly referred to as "Specs." Specifications give detailed instructions regarding materials and methods of work. They cover various factors relating to the job, such as general conditions, scope of work, quality of materials, standards of workmanship, and protection of finished work. The drawings and specifications are inseparable; the drawings indicate what the specifications cannot, and the specifications indicate what the drawings are unable to portray.

FEDERAL SPECIFICATIONS cover the characteristics of materials and supplies used jointly by the Navy, with other Government departments.

MILITARY SPECIFICATIONS are those that have been developed and adopted for use by the Department of Defense. They are identified by "JAN" or "MIL" preceding the first letter and serial number. They were formerly called joint ARMY and Navy Specifications, or "JAN." As they are revised the JAN is being replaced by MIL, but the serial number itself remains the same.

NAVFAC SPECIFICATIONS (formerly Yards and Docks specifications) are prepared by the Naval Facilities Engineering Command and set forth standards of construction. They must conform to specifications set forth by Federal or military procurements. Among NAVFAC specifications that may concern you as a Builder are:

4Yg	Portland Cement Concrete Pavement
7Yk	Roofing and Sheet Metal Work
10Ye	Metal Windows (Steel and Aluminum)
13Yh	Concrete Construction.

On many jobs, you will be furnished written specifications, often called PROJECT SPECIFICATIONS. They apply to the particular job at hand and often contain information on instructions taken from Federal Specifications, Military Specifications, and NAVFAC Specifications.

The specifications should be used together with the drawings when making quantity estimates. When there is disagreement between the specifications and the drawings, the specifications should normally be followed. If in doubt, consult the OICC, Operations, or PW officer for a decision. The estimator should become thoroughly familiar with all the requirements stated in the specifications. Some estimators will have to read the specifications more than once in order to fix these requirements in their minds. Notes made while reading the specifications will prove helpful when examining the drawings. These notes should list items of work or materials which are unusual, items not familiar to the estimator, and reminders for use during examination of the plans.

CONSTRUCTION PLANNING

Planning is the process of determining requirements and devising and developing methods and schemes of action for construction of a project. Proper planning saves time and money for the Navy, and makes the work easier and more pleasant for the work forces involved. It can eliminate friction and confusion, and can free supervisory personnel from many of the details of the work, thus giving them time to carry out other equally important duties. Proper planning expedites the work and eliminates "bottlenecking", (remember that the neck of the bottle is always at its top), and, most important to you personally, it makes your job easier.

As the petty officer in charge, you are responsible for the time utilized by your men, as well as for your own time. You must plan so that your men will be kept busy doing constructive work. This will be to your convenience, and a point to remember is: PLAN AHEAD. Having the men stand around idle each morning while you plan their assignments would be a waste of manpower. At the close of each day, you should confirm planning for the next work day. In doing so, carefully consider factors that have a bearing on the availability and use of manpower, equipment, and materials. In addition to day-to-day planning on the job, the following primary matters should be considered in construction planning: PROJECT ANALYSIS which consists of a study of the job directive and an investigation of the project site, PRELIMINARY PLANNING which includes preliminary estimation and procurement of critical items, and DETAILED PLANNING which includes detailed estimating and scheduling. These considerations are more or less dependent upon each other and are all taken into account in any well-planned project.

PROJECT ANALYSIS

Upon receipt of the job directive and continuing throughout the duration of the project, the planner must constantly consider the following:

1. What is to be done?
2. Where is it to be done?
3. When is it to be done?
4. How should it be done?
5. Why do it this way?
6. If somehing goes wrong, is there an alternate method?

If there is more than one way to do a particular task, is the method selected the best way? Can it be simplified with a resultant saving in time and effort? Application of this analysis to the entire project and to each subtask is an essential element of successful job management.

The job directive may require the constructing unit to select the site for a project either from several tentative locations or within a given area. In this event, one or more reconnaissance teams will be used to study the possible sites. Final selection of the site may be made by the command issuing the directive or it may delegate this authority to the constructing unit. When the issuing command designates a site, the constructing unit must investigate it to determine how it will affect the job to be done. Among the factors the planner must consider in a site investigation are terrain, drainage, accessibility, soil characteristics, existing facilities, natural resources, and weather.

Terrain

What are the terrain features at the site of the proposed construction? Is it mountainous or hilly, or does it consist of prairie, plateau, deposits of soil from water runoff, swamp, or desert? To what extent will forest, vegetation, boulders, slopes, and other obstacles affect the effort and type of equipment necessary to construct a given project? For example, altitude will affect engine performance and man effort; steep slopes and sidehill cuts will reduce the production rate of earthmoving equipment and increase the time and effort necessary to lay out buildings and operate various types of machines.

Drainage

What are the runoff characteristics? Is the site well drained in its natural state? What drainage problems will be present? What effort will be needed to keep it drained during construction? What additional drainage will be required for the finished product?

Accessibility

The planner must examine all aspects of accessibility to determine what problems will be involved in reaching the construction site with equipment and tools, and in delivering materials. From such an examination the capacity of existing roads and other transportation facilities may be learned. Dependent on the conditions found, of course, will be the effort required to build access or auxiliary routes to facilitate movement to, within, and from the construction site. In some instances, this effort might be equal to or greater than that required to construct the basic facility itself.

Soil Characteristics

The nature of soils is of utmost importance in construction. The nature is determined by the type of soil, its moisture content, its molecular structure, the extent to which it may be compacted, and its bearing capacity. The details of information required by the planner will depend on the construction to be executed. In a more complex job, full information on the types of soil at varying depths and the thickness of layers will be of greatest importance, whereas simpler construction may require only the moisture content, bearing capacity, and drainage qualities of the soil at a very shallow depth. The effort required for construction will depend on the nature of the soil. For example, if the bearing capacity of the existing soil is insufficient for the proposed structure the foundation design will have to be modified. This may involve only minor changes such as to the type and size of footings used or it could involve a complete redesign of the foundation. In either case additional manpower, equipment, and materials will be required.

Existing Facilities

The planner must make the fullest use of all improvements that exist on or near the site. Use of existing roads, buildings, and utilities will greatly reduce the task of site preparation. He should, whenever possible, incorporate such improvements into the finished project, thereby reducing the scope of work required.

Natural Resources

Careful reconnaissance of the site and nearby vicinity is required to determine the location of suitable timber, water, aggregate, and borrow material. Location, quantities, distances, and haul roads required, are the primary considerations.

Weather

The planner should obtain local records and forecasts of the weather for the area. From this data a careful estimate is made of expected weather conditions and their effect upon overall progress during the construction period.

PRELIMINARY ESTIMATING

Having familiarized himself with the mission and site conditions, the planner must next determine the capability of the unit to complete the mission. To do this rapidly and with a reasonable degree of accuracy he must estimate and evaluate the following:

1. Materials and work items involved
2. Resources available to the unit
3. Time required
4. Climatic considerations
5. Construction sequence
6. Probable progress

Materials and Work Items

Preliminary estimation and evaluation of the materials and work items involved in a construction project usually begins with the preparation of a Quantity Takeoff Sheet. A quantity takeoff is a listing of all materials placed in a project plus earth excavation and fill. Materials should be listed separately under the tasks which go to make up the project. Listing work items in their normal construction sequence will aid considerably in the later work of more detailed estimating and will aid in the early detection of omissions. The quantity takeoff is made by studying drawings, specifications, plans, and surveys, and then determining what is needed and how much work is involved. In preliminary estimating, accuracy of quantities, within reasonable limits, is secondary in importance to inclusion of all the items involved. Units of measure should be broad ones, such as acres of clearing, miles of road, thousand board feet of lumber, and cubic yards of earthwork or aggregate production. A simple columnar form like the one shown in figure 3-11 may be used to record this information.

Resources Available

The quantity takeoff gives the planner a fairly accurate picture of "what is to be done". He must now determine if the resources available to the constructing unit will enable it to do the job.

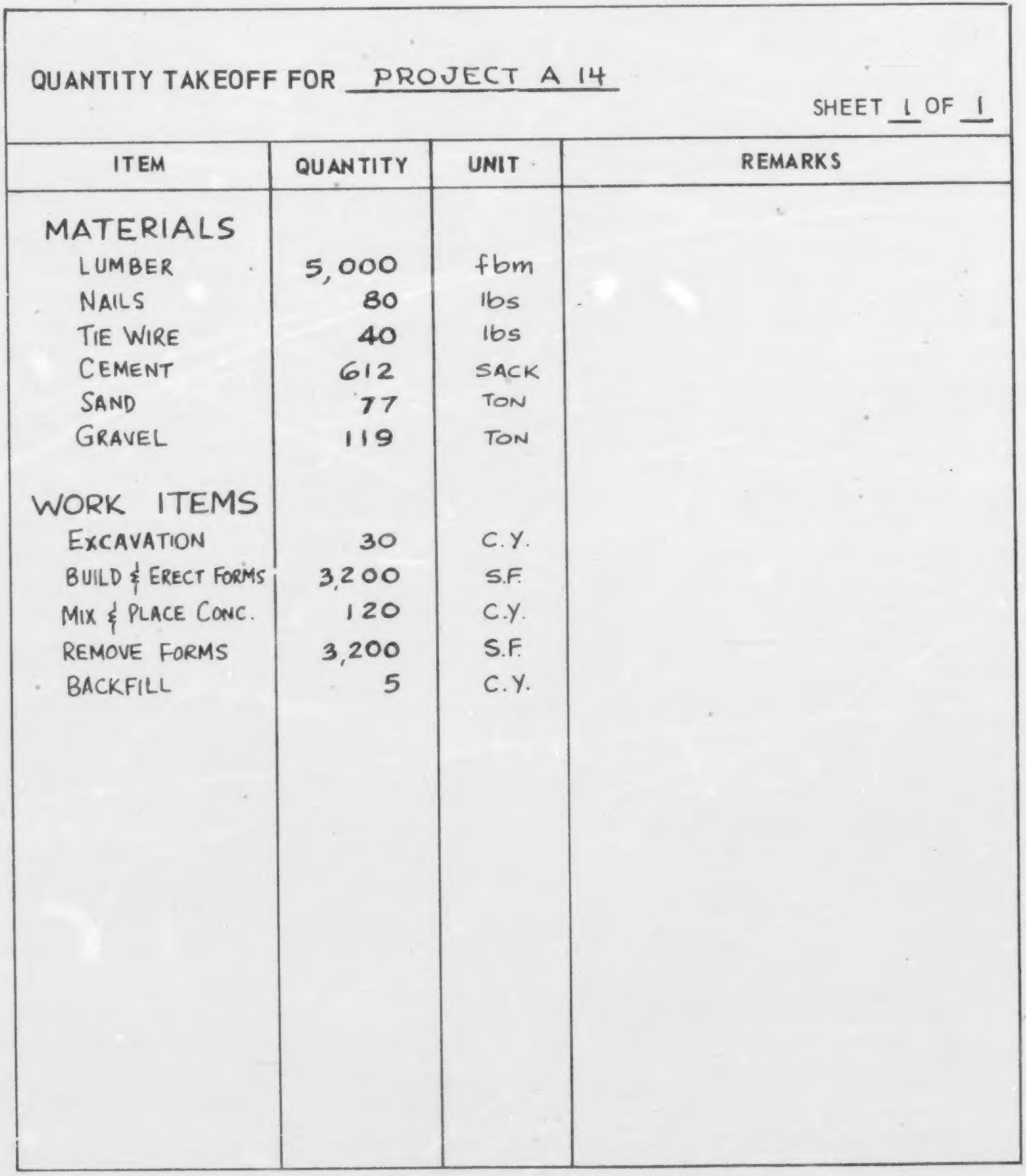
MANPOWER.–Manpower must be considered only in terms of "construction strength". The actual number of men available to work on the job must be used. For example, planners at the battalion level use figures based on previous operational deployments to determine their manpower availability. Based on the current MCB personnel allowance, about 253 men (approximately 45 percent of a full strength unit) are considered as being direct labor and productive in the construction effort. Direct labor being defined as that labor which is expended directly on a project and that contributes to the placement of the end product. This figure may or may not hold true for a particular unit, and should be used for planning purposes only when more exact data is not available. If the project is one that requires large numbers of personnel with particular skills (BUs or CEs, for example) their availability, too, must be taken into account.

Other considerations in determining manpower availability include the state of training of the men available for the construction effort. A full strength battalion with a large number of inadequately trained men will have a low construction output. The ability and number of supervisors and foremen (not included as direct labor or productive personnel) will affect the construction capability of a unit. A shortage of competent supervisory personnel will reduce the construction effectiveness of a unit even though the productive personnel are adequate in number and ability.

EQUIPMENT.–The status of a unit's construction equipment, particularly heavy equipment, is an important factor in determining the unit's ability to do a job. The planner must consider the average deadline rates for items of equipment and judge whether they will be maintained, bettered, or worsened during a particular job. Depending on the nature or type of job, certain items of equipment will be critical in the sense that they will govern the overall progress of the job. Just as earthmoving equipment is critical for road and airfield work, carpenters tools are critical for standard frame structures.

Estimate of Time Required

The planner's next step is the preparation of a rough estimate of the time required to do the



QUANTITY TAKEOFF FOR PROJECT A 14

SHEET 1 OF 1

ITEM	QUANTITY	UNIT	REMARKS
MATERIALS			
LUMBER	5,000	fbm	
NAILS	80	lbs	
TIE WIRE	40	lbs	
CEMENT	612	SACK	
SAND	77	TON	
GRAVEL	119	TON	
WORK ITEMS			
EXCAVATION	30	C.Y.	
BUILD & ERECT FORMS	3,200	S.F.	
MIX & PLACE CONC.	120	C.Y.	
REMOVE FORMS	3,200	S.F.	
BACKFILL	5	C.Y.	

117.305

Figure 3-11. —Typical quantity takeoff.

job. As in the quantity takeoff, extreme accuracy is not required at this stage. Detailed calculations are left for the detailed planning stage. Approximate rates of production based on the unit's experience records are accurate enough. Where this information is lacking, published rates in civilian or military texts *(Seabee Planner's and Estimator's Handbook,* NAVDOCKS P-405, for example) tempered by the planner's knowledge of existing conditions, are a good substitute. The time required to do each major work item developed in the quantity takeoff is calculated, using the available equipment and manpower. Total time for the project is the sum of the times calculated, less the time when two or more work items will be done concurrently. Until more accurate time data is produced in detailed planning, this overall project time is used in planning.

Climatic Considerations

The effect of climatic conditions on construction operations is so great that when planning construction, the evaluation of this one item alone can be as important as all other factors combined. Failure by the planner to consider weather data can result in more time lost because of bad weather than would be needed to finish all the work under favorable weather conditions. The planner must evaluate each type of work that is to be done in relation to the weather conditions expected during the period of construction. For example, in a project involving the construction of various types of heavy structures it may often be desirable, from an equipment viewpoint, to do all the foundation excavating before commencing with foundation construction. This may be done only if there exists a high degree of certainty that there would be little or no precipitation during excavation operations and before adequate drainage could be provided. The evaluation of the expected weather enables the planner to determine how much additional time to allow for weather delays.

Construction Sequence

The sequence in which major operations are to occur is another factor which must be evaluated to some extent in the preliminary planning stage. The sequence of some operations like clearing and stripping, or excavation for and placement of footings, is obvious and does not present a problem. Other sequences, such as materials processing and prefabrication, cannot be determined until later in the detailed planning stage. However, construction sequence has to be considered early in planning because some factors affecting job sequence are present at the very beginning of planning. Among the factors to consider are drainage, availability of materials, natural resources, and weather.

DRAINAGE.–Although the anticipated weather may be almost ideal, and only slight showers expected during the duration of the project, poor existing or natural drainage might allow flooding of the construction site. Therefore, provision for adequate drainage should be made early in the sequence of operations.

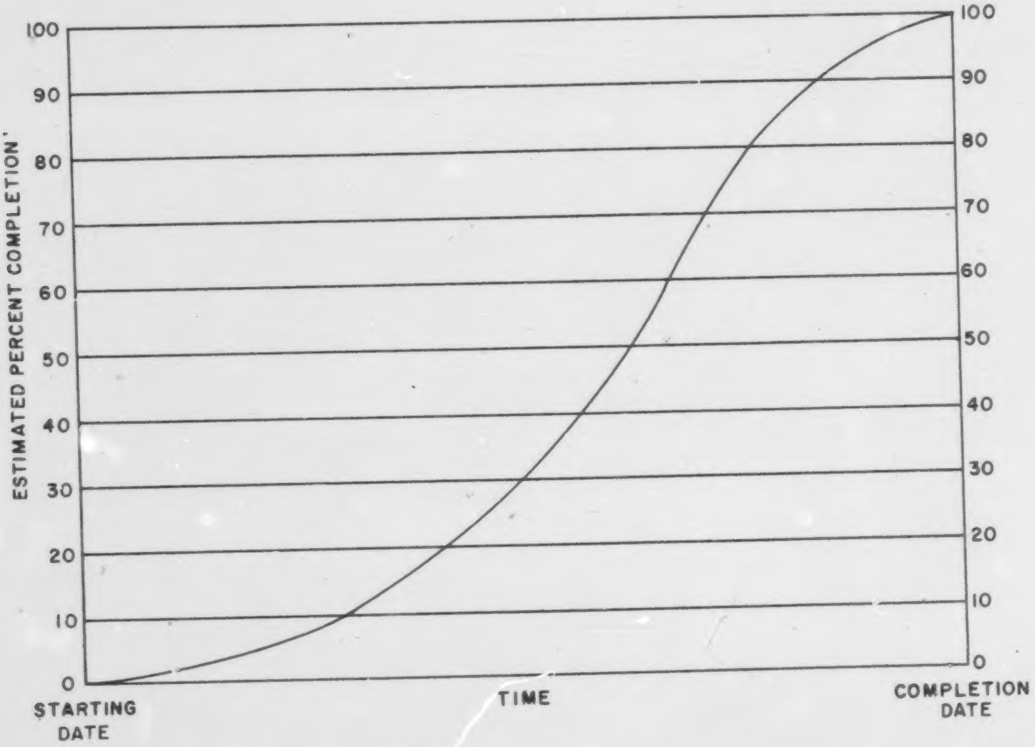
AVAILABILITY OF MATERIALS.–The date of availability of materials will affect job sequence. Operations dependent on materials cannot be started until they are available.

NATURAL RESOURCES.–The location of sources such as quarries or borrow pits has a bearing on construction sequence. When the source of borrow material, for example, is close to one end of an airstrip or road building project it is advantageous to start operations at the end closest to the source of material. When the material is needed it will be placed rapidly since the initial haul distance will be short. Equipment traveling over previously placed material will reduce the amount of compaction effort needed. Starting a job in this way does not reduce the time needed for completion, but it might allow subsequent work to start at an earlier date.

WEATHER.–The anticipated weather, as discussed previously under climatic considerations, will affect job sequence. In a project involving the erection of buildings, for example, the advantage of erecting only the outer shells to permit interior work during inclement weather later, may offset the desirability of completing some buildings first.

Progress Estimate

The next step in the preliminary planning stage is to obtain an estimate of the rate of overall progress of the job. The planner makes his progress estimate on the form shown in figure 3-12. The form is graduated vertically in percent of completion of the job. A flattened S-curve runs from 0 to 100 percent. This curve shows the rate of progress made on the average



117.306

Figure 3-12. –Progress estimate form.

construction job. It was derived from an analysis of many construction projects over a period of several years. The curve shows that in the initial stages of a project, little progress is made because of such necessary preliminaries as moving in to the job, mobilizing equipment, and getting early operations under way. As the project develops, operations gain momentum, and the rate of progress increases. When the project is about 90 percent complete, the rate of progress falls off, because major operations are completed and the job approaches the finishing stage. Finishing operations, such as fine grading or installing millwork, have a slow rate of production. When the project reaches the cleanup stage, the rate of progress gets very low. A great deal of time is used to clean the job up, complete the many small jobs, turn the finished product over to the using agency, and, finally, move off the job.

The estimate of the time required for the job (discussed earlier) is used to complete the form. The estimated time is divided into convenient equal time segments (days or weeks, for example). These are placed as horizontal time divisions on the chart. For example, if a job is estimated as taking 10 weeks to complete, the form is divided horizontally into 10 equal parts. When this is done it may be seen that at the end of 2 weeks, 5 percent of the job should be done; at the end of 5 weeks, the halfway point, about 30 percent; and at the end of 8 weeks, about 85 percent. The form enables the planner to realistically estimate in advance how much of the job should be done at a given time. This will be helpful in scheduling and control. The form also assists in programming the delivery of materials which must be ordered before completion of the material delivery schedules which will be developed in detailed planning.

Procurement of Critical Items

During the preliminary planning stage, the planner should keep notes on materials and equipment that may be critical to the job. They may be critical because they are needed immediately for the job, because they are not available locally, or because a long lead time for procurement will be required. The entire job and the notes should be studied, such items tabulated, and action taken to ensure that they will be on hand when required.

PROJECT ANALYSIS AND PRELIMINARY PLANNING gives the military construction manager a quick overall picture of the assigned task and the capacity of the constructing unit to accomplish it. It serves as a guide to the DETAILED PLANNING which follows. Detailed planning develops an accurate estimate of the materials, labor, and equipment to do each of the subtasks in a construction project, and a schedule for the entire project. As mentioned earlier, detailed planning includes detailed estimating and scheduling.

CONSTRUCTION ESTIMATING

If any one step in planning a construction project may be considered the most important, it is estimating. The failure or success of a civilian construction firm depends to a great degree on the accuracy of its estimates. Overly high estimates result in loss of contracts; estimates which are too low result in acceptance of contracts which may have to be completed at a loss. In military construction, faulty estimates may lead to failure to meet completion dates; may cause uneconomical use of men, materials, and equipment; and may seriously jeopardize a tactical or strategic situation. To help ensure accuracy, quantity estimates should be checked in a manner that will eliminate as many errors as possible. One of the best ways to check a quantity estimate is to have another person make an independent estimate and then compare the two estimates after both are completed.

A good SEABEE estimator should be able to mentally picture the separate operations of the job as the work will progress through the various stages of construction. He should have previous construction experience and must be able to do careful and accurate work free of errors. A SEABEE estimator should possess ability to use good judgment when determining what effect numerous factors and conditions will have on construction of the project and what allowances should be made for each of them. He should have available to him information about materials, equipment, and labor that is required to perform various types of work under conditions encountered in accomplishing SEABEE construction projects. Collection of such information on construction performance is part of the job of estimating. Reference information of this kind may change from time to time, and therefore should be revised frequently. An estimator, working either by himself or as a member of a team, may often be required to plan construction and prepare estimates for other construction ratings as well as his own. So, in addition to knowing his own specialty, a good estimator should have a working knowledge of other branches of construction for which he will have to draw up estimates.

At this point, let us remind you that various procedures are used in estimating for construction work, and those described here are suggested procedures rather than standard procedures. You must use judgment as to when the procedures can be applied effectively; and, in some cases you may want to make revisions in a procedure to make it more suitable to the particular project being estimated.

Another point to remember is that various forms are used in planning and estimating, and those described here are typical forms rather than standard forms. By careful study of the principles of job planning and estimating, you will be equipped with sufficient information to enable you to utilize forms like those shown, or prepare your own forms in accordance with the objectives of planning and estimating.

WORK ELEMENT ESTIMATES

A work element estimate is a listing of the quantities of each work element (such as square feet of surface area) required to construct a given project. Work element estimates are prepared by computing the quantities of the various items of work shown or referenced by notes on the drawings and described in the specifications. You may sometimes hear work element estimates called Quantity Takeoffs. The distinction between the two being the degree of accuracy and the amount of detail taken in their preparation.

If you recall in the previous discussion on preliminary planning, Quantity Takeoffs were used to aid in determining the capability of a construction unit by providing the planner with a fairly accurate picture of "what is to be done". Broad units of measure were used in their preparation with major emphasis being placed on the inclusion of all work items. These now can be used as a guide and as a check against omissions in the development of the more detailed and accurate work element estimates.

Work element estimates provide the basis for preparing estimates of material, equipment, and manpower requirements. For example, the work element estimate might show 1,000 square feet of 12" concrete block wall to be constructed. In the materials estimate, this would be converted into required quantities of mortar sand, portland cement, lime and 12" concrete block. In the equipment estimate, it would be converted into mixer time required to mix the mortar. In the manpower estimate, the work element quantity would be converted into the number of man-days required to perform the work. The quantity of block wall together with information on work sheets such as length and height of wall would be used to estimate the number of scaffold frames and scaffold boards required, together with requirements of special tools such as mortar boxes and hods. Information shown in work element estimates is also used in scheduling progress, which provides the basis for scheduling material deliveries, equipment, and manpower.

An estimator should have a good general knowledge of the project to be constructed before performing any actual takeoff of quantities. This knowledge can be obtained by an overall study of the drawings, reading the specifications, and examining all available information about the project site and local conditions compiled during the project analysis and preliminary planning phases of construction planning. After he has become familiar with the project, the estimator is ready to begin measuring and recording quantities of materials for the work elements.

The normal practice when measuring quantities is to begin by measuring work elements on the foundation and footing plan and to proceed through the basement and each succeeding floor plan of the architectural and structural drawings. All reference and detail drawings that refer to a particular plan are examined and worked in conjunction with that plan. After examination of the plans, the elevations and then the details are examined one by one, and all materials not previously taken off are measured and recorded. Often concrete, reinforcing, and structural features are shown on drawings separate from the architectural features. When this is done, it is best to work the concrete and reinforcing drawings first, followed by the architectural drawings. After completing the architectural and structural drawings, the mechanical, and then the electrical drawings are worked, and these are followed by any available specialty, civil, or shop drawings. These drawings should always be examined in this order: Plan drawings first, next elevations, and then details.

When measuring quantities on a drawing, it is better to begin at one side and work towards the opposite side, marking with a colored pencil the particular work as it is measured and recorded. Work such as concrete, reinforcing, and similar items can be marked with a simple check (√), but items such as conduit and piping should be marked by tracing over the part measured with a colored pencil. The colored marks not only show the estimator what has been taken off, thus preventing duplication, but provide a means of checking a drawing for omissions.

As each work element is measured, the information is recorded and computations are shown on a worksheet. The heading of each worksheet should show the following: That it is a work element estimate worksheet, the worksheet number, estimator's name, date of takeoff, checker's name, date checked, battalion number, deployment location, year, project number, and project description. The description, location, measurement, computations, quantity of the work element, drawing numbers, drawing revision, and date of latest drawing issue should all be shown in the body of the worksheet. Work elements are entered on the worksheet in the same order as they are measured on the drawing sheet regardless of type of work. A typical worksheet is shown in figure 3-13. Usually all measurements from one sheet of a drawing are entered on the worksheet before computations of quantities are made. Computations are made in the units of measurement on the drawings; for example, concrete is computed and totaled in cubic feet with the total converted to cubic yards.

A summary of work element quantities is prepared by transferring the totals on the worksheets to a summary sheet, which becomes the work element estimate. Work elements are arranged in the same sequence as they appear in the standard work element list so they will be in correct sequence for reporting or recording on work schedules. For example, concrete block is listed after erection of precast concrete members and before brickwork. Standard work element lists referred to in this manual are as promulgated by appropriate COMCBLANT/COMCBPAC instructions. This summary sheet has the same information in the heading as the worksheet, except that it is shown as a work element estimate summary sheet. The body of the summary sheet shows the description and quantity of the work elements. If decisions have been made as to how the work will be accomplished, this is indicated by the entry—for example, excavation is entered as machine excavation and backfill as machine backfill. A typical work element estimate summary sheet is illustrated in figure 3-14.

Before proceeding, note that the forms shown in figures 3-13 through 3-16 of this discussion illustrate the minimum amount of information which should appear on such forms, and should NOT be considered as standard worksheets. Some estimators may wish to record additional information, or they may desire to record their work in a different manner. A main object to keep in mind is that the recording is to be detailed in such manner that anyone reviewing the estimate can understand what was taken off and how computations were made. If this procedure is followed, an independent check can be made without questioning the estimator as to how he arrived at any quantity in the estimate.

MATERIAL ESTIMATES

A material estimate is a listing and description of the various materials and the quantities required to construct a given project. Information for preparing material estimates is obtained from drawings and specifications. A material estimate is sometimes referred to as a Materials Takeoff.

Material estimates are used as a basis for construction material procurement, and also as a check to determine if sufficient materials are available to construct or to complete a project. For example, the operations officer might have some doubts about availability of materials to complete a certain project, so an estimate is prepared listing quantities of materials that will be required to complete the project. This estimate is compared with the stock of materials on hand to determine any shortage.

The following is a suggested procedure for preparation of a material estimate. First, obtain the work element quantity, which is usually done by referring to the work element estimate. Convert this into quantities of materials required to perform the work. (Conversion units obtained from tables supplied by Naval Schools, Construction courses should be used whenever possible.) This conversion should be done on a worksheet which will record how each material quantity was obtained.

Figure 3-15 illustrates the type of information shown on a typical material estimate worksheet. Each worksheet should have a heading that shows it is a material estimate worksheet, the sheet number, estimator's name, date estimated, checker's name, date checked, the battalion number, deployment location, year, project number, and description of the project. The body of the worksheet should show element and material description, work element quantity, conversion unit, quantity of material required, and remarks. It is important that worksheets be sufficiently detailed to be self-explanatory, so that anyone examining them can determine how quantities were computed without consulting the estimator. Sometimes if desired, a sketch furnished will explain how the estimator planned the takeoff.

After computing material quantities on the worksheets, enter them on recap sheets with like

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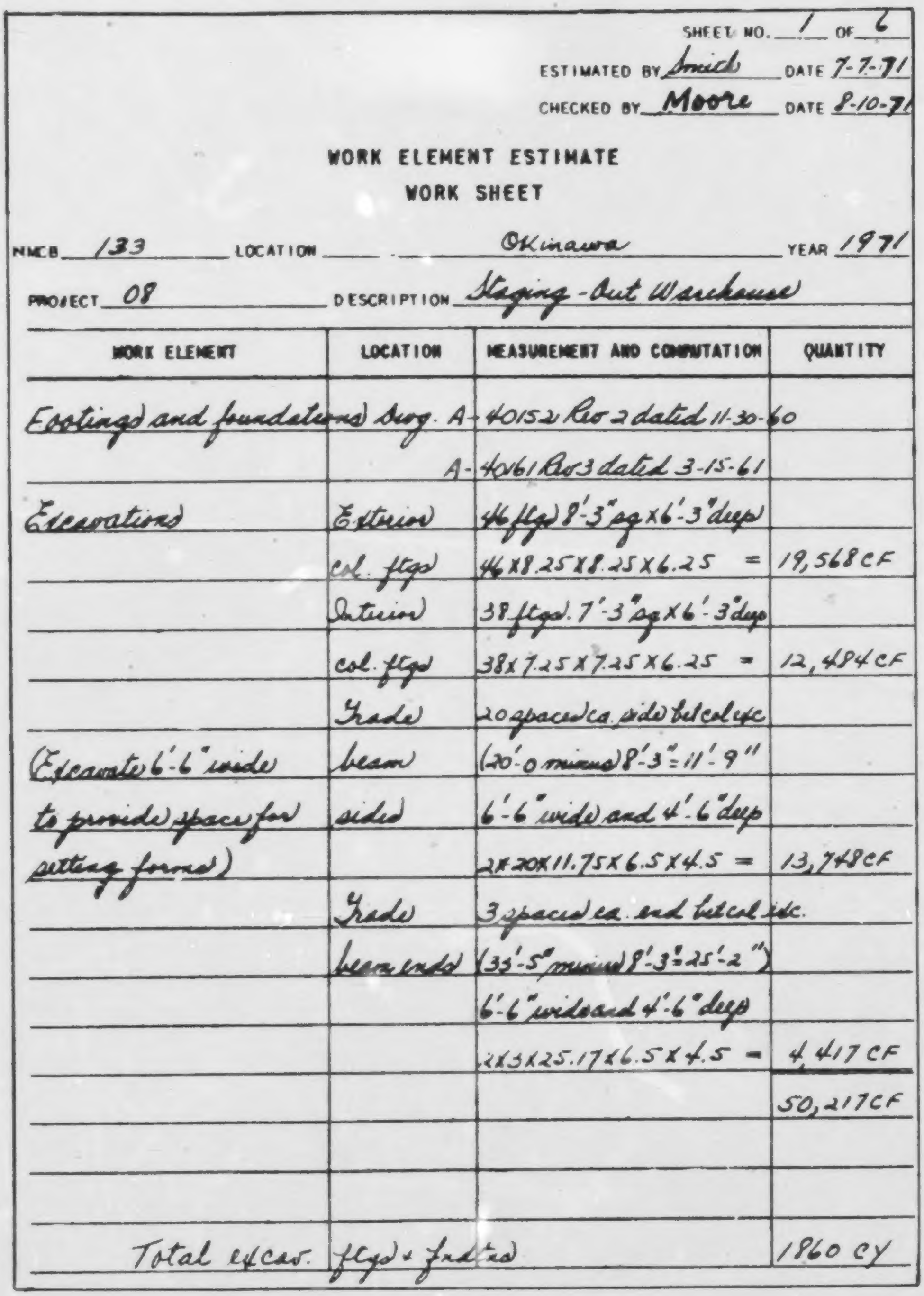


SHEET NO. 1 OF 6
ESTIMATED BY Smith DATE 7-7-71
CHECKED BY Moore DATE 8-10-71

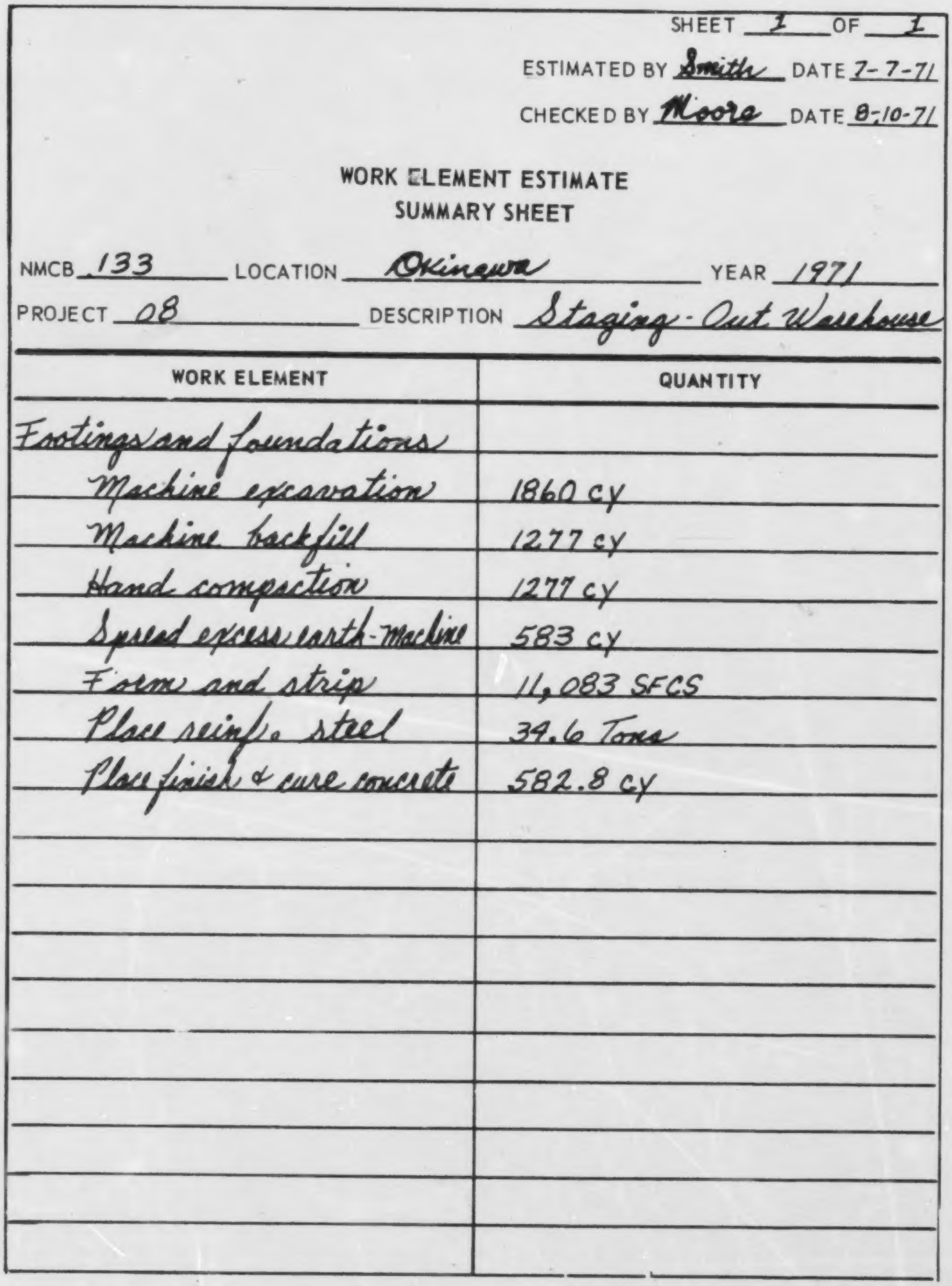
WORK ELEMENT ESTIMATE
WORK SHEET

NMCB 133 LOCATION Okinawa YEAR 1971
PROJECT 08 DESCRIPTION Staging-Out Warehouse

WORK ELEMENT	LOCATION	MEASUREMENT AND COMPUTATION	QUANTITY
Footings and foundations	Dwg. A-	40152 Rev 2 dated 11-30-60	
	A-	40161 Rev 3 dated 3-15-61	
Excavations	Exterior	46 ftgs 8'-3" sq x 6'-3" deep	
	col. ftgs	46x8.25x8.25x6.25 =	19,568 CF
	Interior	38 ftgs. 7'-3" sq x 6'-3" deep	
	col. ftgs	38x7.25x7.25x6.25 =	12,484 CF
	Grade	20 spaces ea. side bet col c/c	
(Excavate 6'-6" wide	beam	(20'-0 minus 8'-3" = 11'-9"	
to provide space for	sides	6'-6" wide and 4'-6" deep	
setting forms)		2x20x11.75x6.5x4.5 =	13,748 CF
	Grade	3 spaces ea. end bet col c/c.	
	beam ends	(33'-5" minus 8'-3" = 25'-2")	
		6'-6" wide and 4'-6" deep	
		2x3x25.17x6.5x4.5 =	4,417 CF
			50,217 CF
Total excav.	ftgs + fndtns		1860 CY

82.88

Figure 3-13. –Work element estimate worksheet.



SHEET 1 OF 1

ESTIMATED BY Smith DATE 7-7-71

CHECKED BY Moore DATE 8-10-71

WORK ELEMENT ESTIMATE
SUMMARY SHEET

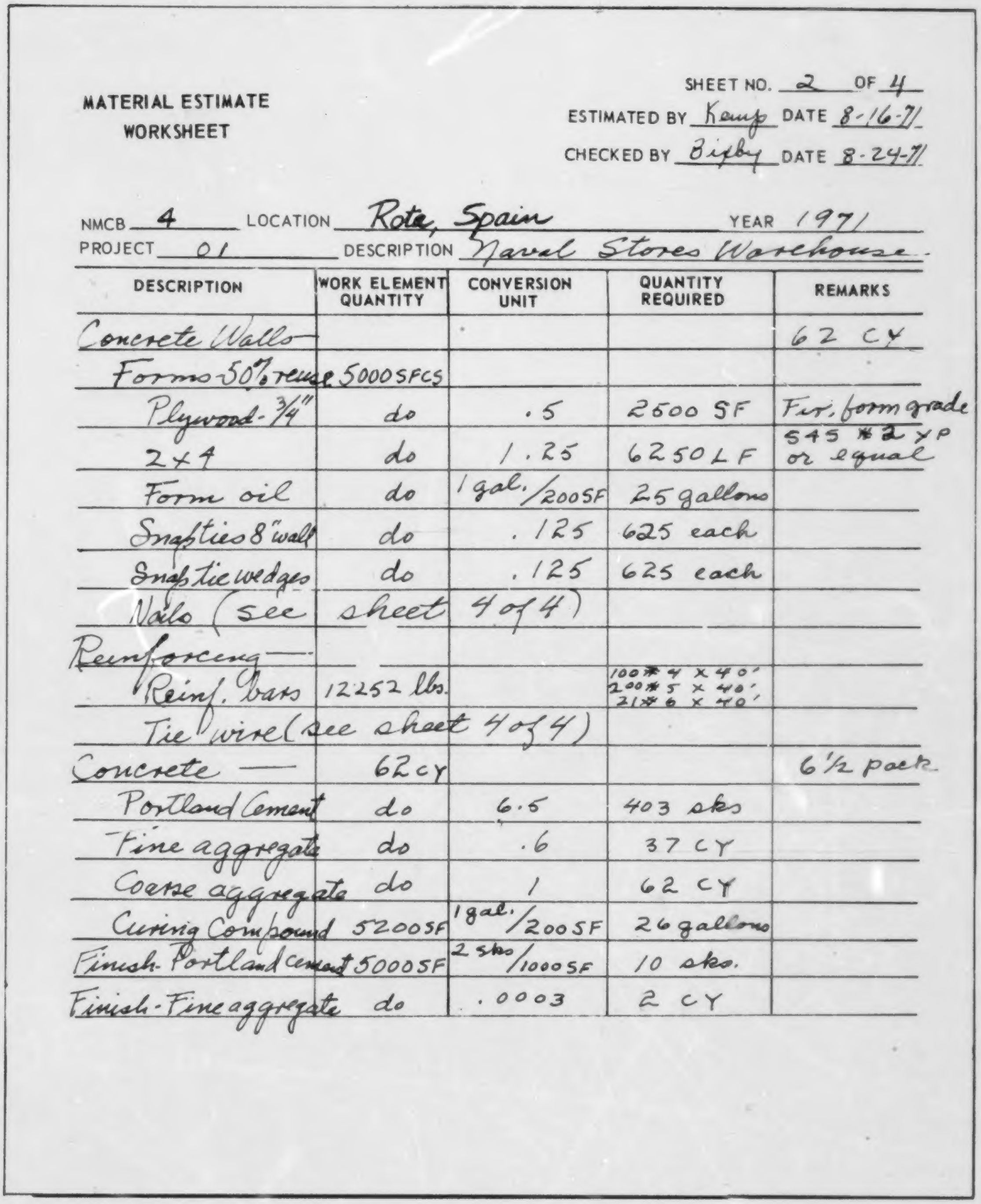
NMCB 133 LOCATION Okinawa YEAR 1971

PROJECT 08 DESCRIPTION Staging-Out Warehouse

WORK ELEMENT	QUANTITY
Footings and foundations	
Machine excavation	1860 cy
Machine backfill	1277 cy
Hand compaction	1277 cy
Spread excess earth-machine	583 cy
Form and strip	11,083 SFCS
Place reinf. steel	34.6 Tons
Place finish & cure concrete	582.8 cy

145.4

Figure 3-14. —Work element estimate summary sheet.



MATERIAL ESTIMATE WORKSHEET

SHEET NO. 2 OF 4
ESTIMATED BY Kemp DATE 8-16-71
CHECKED BY Bixby DATE 8-24-71

NMCB 4 LOCATION Rota, Spain YEAR 1971
PROJECT 01 DESCRIPTION Naval Stores Warehouse

DESCRIPTION	WORK ELEMENT QUANTITY	CONVERSION UNIT	QUANTITY REQUIRED	REMARKS
Concrete Walls —				62 CY
Forms-50% reuse	5000 SFCS			
Plywood-3/4"	do	.5	2500 SF	Fir, form grade
2×4	do	1.25	6250 LF	S4S #2 YP or equal
Form oil	do	1 gal./200 SF	25 gallons	
Snapties 8" wall	do	.125	625 each	
Snaptie wedges	do	.125	625 each	
Nails (see	sheet	4 of 4)		
Reinforcing —				
Reinf. bars	12252 lbs.		100 #4 × 40' 200 #5 × 40' 21 #6 × 40'	
Tie wire (see sheet 4 of 4)				
Concrete —	62 CY			6½ pack
Portland Cement	do	6.5	403 sks	
Fine aggregate	do	.6	37 CY	
Coarse aggregate	do	1	62 CY	
Curing Compound	5200 SF	1 gal./200 SF	26 gallons	
Finish-Portland cement	5000 SF	2 sks/1000 SF	10 sks.	
Finish-Fine aggregate	do	.0003	2 CY	

87.2

Figure 3-15. —Material estimate worksheet.

materials for a project grouped together and totaled. Allowances for waste and loss are added after the quantities are totaled. There are some items, such as reinforcing tie wire and nails, which are computed using a material quantity rather than a work element quantity. These computations should appear at the end of the worksheets, using total quantities obtained from the recap worksheet. Notes should be made on the worksheet to remind the estimator that these items are to be compared using total quantities from recap sheets. The recap worksheet becomes the material estimate. A sample of a typical recap worksheet is shown in figure 3-16.

The recap worksheet has the same information in the heading as the material estimate worksheet, except that it is shown as a material estimate recap worksheet. The body of the recap worksheet should show material description, quantity, waste and loss factor, waste and loss quantity, total quantity to procure, and remarks.

During construction there is a certain amount of material wasted due to cutting, fitting, and handling. For example, lumber comes in standard lengths which seldom can be used without cutting and fitting. Sometimes the pieces of lumber cut off can be used, but more often it goes into the scrap pile. Allowance must be made in the materials estimate for this waste. There is also the possibility of loss due to pilferage, and weather. Waste and loss factors as supplied by Naval Schools, Construction are based on a large number of jobs performed under varied conditions and at many different locations. An estimator has specific information about the job and is in a position to determine if conditions warrant increasing the waste and loss factor normally used for any material item. And, he should not hesitate to vary this waste and loss factor when job conditions indicate that normal factors are too low.

EQUIPMENT ESTIMATES

An equipment estimate, for purposes of this discussion, is a listing of the type of equipment, the amount of time and the number of pieces required to construct a given project. Information from work element estimates, drawings and specifications, and information obtained from inspection of the site provide the basis for preparing the equipment estimate.

Equipment estimates are used together with work schedules as a basis for determining the construction equipment requirements of a project and the total construction equipment requirements of a SEABEE deployment. This estimate includes such items as mortar mixers, wheel barrows and chain saws, as well as automotive equipment. Equipment estimates may also be used as a basis for estimating the amount of spare parts, the number of mechanics, the size of shops, and the tools and shop equipment needed to maintain construction equipment in operating condition during a deployment.

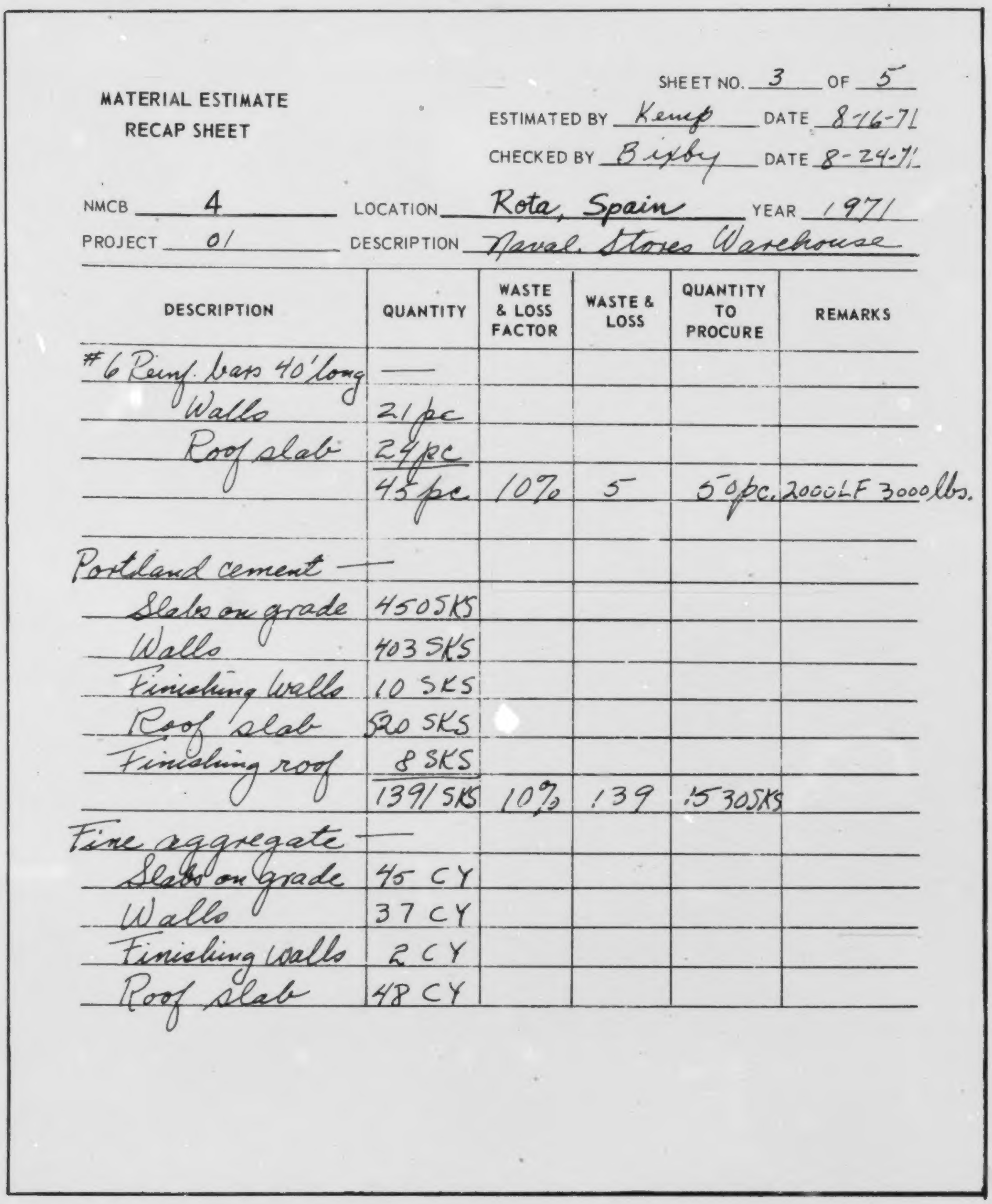
There is no standard format for an estimate of equipment production. The estimator decides on a format which will show what he considers necessary for the estimate. Figure 3-17 illustrates the type of information and format of one of the more commonly used types of equipment estimates. As a minimum the estimate should list the work item, quantity, type of equipment, rate of production, and time required. Figure 3-18 illustrates a format for equipment estimating which contains these items and several others titled and used as follows:

ITEM NO. This column indicates the sequence in which each work item is to be done and serves as a simple, ready reference to the work item.

LOCATION. This column shows where each item of work will take place. In road and airfield projects, actual stationing is shown. When the job is under way the field supervisor can flag the stationing points and assign equipment accordingly.

AVERAGE HAUL DISTANCE. This column serves the field supervisor as a guide in making decisions as to job layout.

WORKSHEET NO. This column identifies the worksheet on which the calculations for the work item estimate concerned were made. It serves as a ready reference for checking any questionable estimates.



MATERIAL ESTIMATE
RECAP SHEET

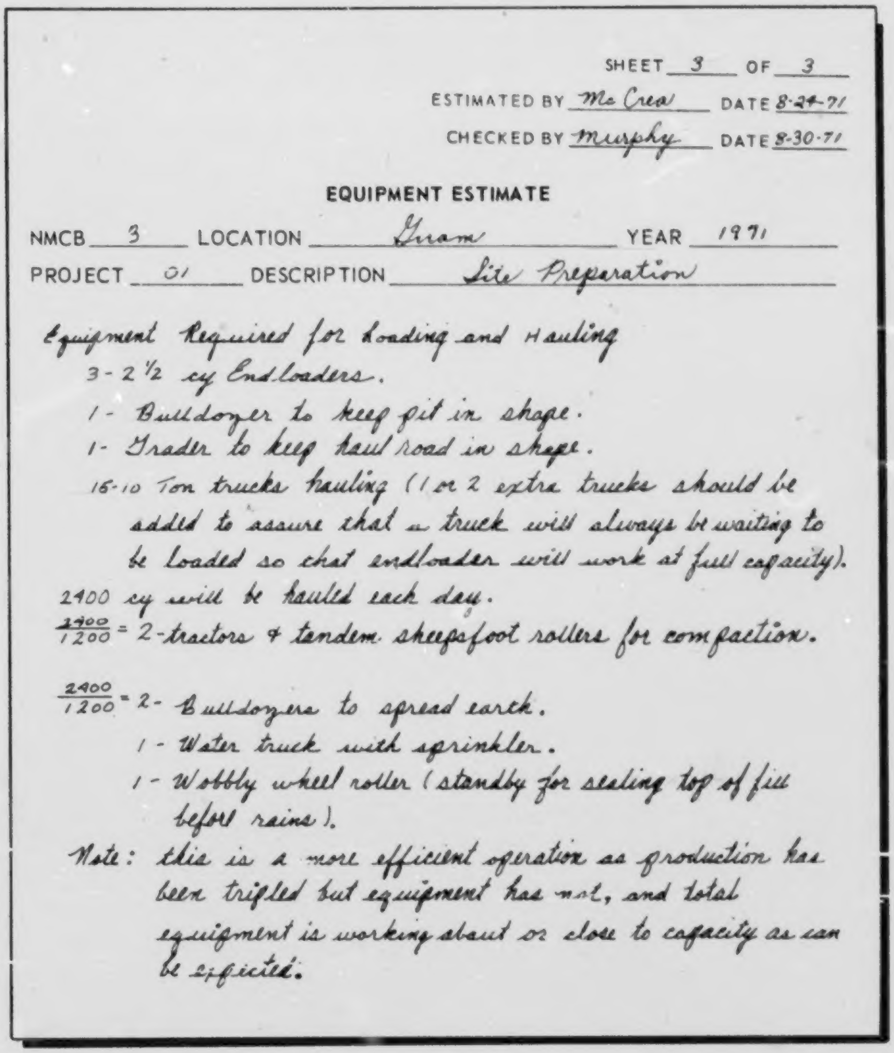
SHEET NO. 3 OF 5
ESTIMATED BY Kemp DATE 8-16-71
CHECKED BY Bixby DATE 8-24-71

NMCB 4 LOCATION Rota, Spain YEAR 1971
PROJECT 01 DESCRIPTION Naval. Stores Warehouse

DESCRIPTION	QUANTITY	WASTE & LOSS FACTOR	WASTE & LOSS	QUANTITY TO PROCURE	REMARKS
#6 Reinf. bars 40' long	—				
Walls	21 pc				
Roof slab	24 pc				
	45 pc	10%	5	50 pc.	2000 LF 3000 lbs.
Portland cement —					
Slabs on grade	450 SKS				
Walls	403 SKS				
Finishing walls	10 SKS				
Roof slab	520 SKS				
Finishing roof	8 SKS				
	1391 SKS	10%	139	1530 SKS	
Fine aggregate —					
Slabs on grade	45 CY				
Walls	37 CY				
Finishing walls	2 CY				
Roof slab	48 CY				

87.3

Figure 3-16. —Material estimate recap sheet.



SHEET 3 OF 3
ESTIMATED BY Mc Crea DATE 8-24-71
CHECKED BY Murphy DATE 8-30-71

EQUIPMENT ESTIMATE

NMCB 3 LOCATION Guam YEAR 1971
PROJECT 01 DESCRIPTION Site Preparation

Equipment Required for Loading and Hauling
3 - 2 1/2 cy Endloaders.
1 - Bulldozer to keep pit in shape.
1 - Grader to keep haul road in shape.
15-10 Ton trucks hauling (1 or 2 extra trucks should be added to assure that a truck will always be waiting to be loaded so that endloader will work at full capacity).
2400 cy will be hauled each day.
$\frac{2400}{1200}$ = 2-tractors & tandem sheepsfoot rollers for compaction.

$\frac{2400}{1200}$ = 2- Bulldozers to spread earth.
1 - Water truck with sprinkler.
1 - Wobbly wheel roller (standby for sealing top of fill before rains).
Note: this is a more efficient operation as production has been tripled but equipment has not, and total equipment is working about or close to capacity as can be expected.

145.5

Figure 3-17. —Equipment estimate.

DELAY FACTOR. This column contains the actual factor determined for and applied to each item of work.

A format such as this serves many useful purposes. It channelizes and coordinates the efforts of the estimator, thus saving time in its preparation. It simplifies checking and verification when completed. It gives the field supervisor a clear picture of what is to be done and how it is to be done. It gives the field supervisor definite targets to meet in unit rates and production time. It facilitates accurate comparison of estimated rates, delay factors, and production times with those actually obtained on the job and simplifies later analysis to determine reasons for any wide variations that might occur.

When preparing the equipment estimate, the work element estimate should be examined and all work elements requiring equipment for their performance should be listed. For each work

WORK ESTIMATE SHEET

PROJECT ______________________________ SHEET __________ OF __________

ITEM NO.	LOCATION	WORK ITEM	AVER. HAUL DIST.	EQUIPMENT	WORK SHEET NO.	QUANTITY	UNIT RATE	HOURS	DEL'Y. FAC'R.	HOURS
									TOTAL	

117.307

Figure 3-18. —Work estimate format.

element on this list, the type of equipment and method of performing the work should be selected. The production rate per day should be estimated for each piece of equipment. The quantity of work is divided by the production rate per day to find out how many days of operation are required to perform the work. You will be briefed later in this discussion on various factors affecting production and on sources of information used in determining equipment production rates. Some elements of work require several items of equipment to be used as a group rather than individually; in these cases, the days of operation should be shown as days of group operation.

After determination of the number of days of equipment operation required, the work schedule should be consulted to find the time allotted for completion of the work element. It may be necessary to work several pieces or groups of equipment at the same time in order to complete the work within the scheduled time. Also, it may be advantageous to use several pieces or groups of equipment at the same time because it would result in more efficient operation. An equipment schedule should be prepared for the total deployment using the work schedule to determine when the work will be performed. The number of pieces of each equipment type required at any one time can be determined from this schedule. This schedule will indicate the peak workloads for each equipment type. A study of the peak loads may show that it is desirable to revise the work schedule to more evenly distribute the equipment workload and thereby reduce the amount of equipment required for a deployment.

Following a review of the equipment and work schedules, and making all possible adjustments to them, a list of the equipment requirements for the deployment can be prepared. In preparing this list, downtime should be anticipated and sufficient equipment added so that when equipment is out of service awaiting repairs a reserve piece is available for use. This is especially important for automotive equipment. The number of pieces of equipment required for a deployment is obtained by adding the required reserve equipment of each type to the peak figure indicated by the equipment schedule.

Factors Affecting Production

When you realize the importance of equipment in getting construction work done, you can see that special care is needed in preparing equipment estimates. You will often have to consider a number of factors before arriving at an estimate of how much work to expect from an individual piece of equipment. Some of the important factors affecting equipment production are: average speed at which the equipment will be operated, type of materials to be handled, experience of operators, age and condition of the equipment, time allotted for completion, climate, and safety.

EQUIPMENT SPEED.–Maximum speeds are established either by a governing authority such as a highway or street speed limit, or by a command such as an operating limit on the equipment. In either case the speed limits must be considered when estimating the average hauling speed which, in turn, determines the amount of material the equipment will move in one day. The estimator should not make the mistake of using the speed limit as the average speed at which equipment will be operated. Equipment speed will usually average 40 percent to 65 percent of speed limits depending upon condition of the road, number of intersections to be crossed, amount of traffic and length of haul. Longer hauls will usually result in higher average speeds, other conditions being equal.

TYPE OF MATERIAL TO BE HANDLED.–The type of material to be handled has a definite effect on the amount of time required. For example, wet sticky clay is slower to dig, load, and dump because it sticks to the bucket, pan, or truck bed, and requires jarring and shaking to loosen and dump the load. On the other hand, damp sandy loam does not stick to buckets, beds or pans and requires little or no jarring or shaking; therefore, the time required for these extra maneuvers is saved. Sand handles easier and quicker with a clamshell bucket than does gravel or crushed rock. When lifting with a crane, bulky, hard-to-rig material and equipment require more time to load and unload. For example, a large timber or steel beam is easy to handle by simply putting a choker sling around the midpoint and lifting while a large bulky piece of equipment would require bridle slings placed so as to balance the equipment as it is lifted. Several trial lifts usually are required, moving the slings after each lift, before the equipment is balanced for safe lifting.

EXPERIENCE OF OPERATORS.–The experience of the operator must be given consideration when estimating production of equipment. An experienced man operating equipment knows the short cuts and performs work with minimum effort and movement, thus getting maximum production from a machine. For example, an experienced operator will spread a load of dirt with less passes than an inexperienced man and do a better job of spreading. Also, inexperienced operators are likely to forget some of the required maintenance operations and as a result, tend to have more downtime with their equipment.

AGE AND CONDITION OF EQUIPMENT.–The age and condition of equipment certainly must be considered in estimating the number of days required to perform work. Old equipment and poorly maintained equipment are more likely to have downtime than new equipment or equipment in good operating condition. Also, old and worn equipment responds more slowly to the operator, has less power and is generally less efficient. Downtime of equipment sometimes affects more than just its own operation. For example, if one of five trucks hauling dirt broke down it would affect only its own operation, but if the equipment loading those five trucks broke down it would stop all of the trucks plus the equipment spreading and compacting the dirt being hauled.

TIME ALLOTTED FOR COMPLETION.–The time allotted for completion affects production if crews must work long hours daily, or if work must be performed under crowded conditions in order to complete the project within the allotted time. Men working long hours daily without sufficient rest and relaxation tend to slow down, especially if this continues for several weeks, and production per machine and per man is lowered. Also, when work is performed under crowded conditions, efficiency drops, and production is lowered. More efficient operation and better production are usually obtained by working two or more shifts per day.

CLIMATE.–Climate, of course, has a considerable effect on production of equipment in outside work. Rain slows down the work, and frequently stops it for the remainder of the day and sometimes for several days. In climates with considerable rainfall, as in Okinawa, equipment will not produce as much per hour or per week as in dry climates. Extremely cold weather slows down the operator and lowers the efficiency of the equipment, thus lowering production. Climate also has an effect upon the spare parts required to maintain equipment in operating condition and should be considered when determining spare part requirements. Very dry climates with considerable dust cause more rapid wear on parts such as engines and bearings, while wet climates with equipment operating in mud cause more rapid wear on parts such as track assemblies.

SAFETY.–Safety factors sometimes limit the amount of work which can be produced with a machine, and therefore they must be considered as a production factor. For example, although the manufacturer's crane rating may show it to be capable of lifting 40 tons with a 70-foot boom at a 45° angle, for reasons of safety the maximum lifting capacity of that particular crane may have been limited to 85 percent of the manufacturer's rating. The crane can then only be used to lift 34 tons with a 70-foot boom at a 45° angle. Certain pieces of equipment may have their speed limited because of safety reasons, which would reduce the rate of production as discussed earlier in the section on "Equipment Speed".

Equipment Production Rates

Numerous sources of information about equipment production rates are available. These sources include manufacturer's tables and diagrams, Government manuals, and estimating books. Production rates are usually available in most SEABEE operations offices. However, it is not practical to draw up a production table which would consider the particular combination of factors affecting production on a given project. Production rates found in tables, therefore, must be adjusted to fit the conditions expected on the particular project being estimated. In order to make the adjustment intelligently, the estimator should know on what basis the rate in the table was established. This information is usually contained in the foreword, in notes for the table, or in instructions for using the table.

MANPOWER ESTIMATES

A manpower estimate is a listing of the number of man-days required to complete the various work elements of a specific project. These estimates may show only the man-days for each work element and the total man-days, or they may be in sufficient detail to show the number of man-days of each rating–such as Builder, Steelworker, Utilitiesman, and so on–for each work element. Manpower estimates are used in determining the number of men and ratings required on a deployment, and provide the basis for scheduling manpower in relation to construction progress. Two types of manpower estimates that you may prepare are preliminary and detailed estimates.

PRELIMINARY manpower estimates are estimates prepared from limited information, such as general descriptions of projects, or preliminary plans and specifications containing little or no detailed information. They are usually prepared on the basis of area, length, or other suitable general dimensions, to establish rough cost estimates for budget purposes and/or to program manpower broadly for succeeding years.

DETAILED manpower estimates are more accurate estimates, used to determine manpower requirements for specific projects.

Manpower Estimating Tables

For both preliminary and detailed manpower estimates, you will probably have available manpower production rate tables relating to all the common types of construction work. Figure 3-19 shows a preliminary manpower estimating table from the *Seabee Planner's and Estimator's Handbook.* In preparing preliminary estimates on the basis of area or linear measurement, it is first necessary to compute the area or other measurement of the project from information at hand. Next the conditions under which it will be constructed must be considered, and a suitable man-day per unit figure selected. The quantity of measurement is then multiplied by the

ROAD, WALK, PARKING AREA AND FENCE INSTALLATION

WORK ELEMENT DESCRIPTION	UNIT	MAN-DAYS PER UNIT		
		ADVERSE CONDITION	AVERAGE CONDITION	FAVORABLE CONDITION
For preliminary estimates only:				
Roads (including grading and base)				
Asphalt	1000 SY	130	65	27
Concrete	1000 SY	240	140	67
Gravel	1000 SY	75	45	20
Concrete curbs	1000 LF	260	160	75
Parking areas (includes grading, base, and curbs)				
Asphalt	1000 SY	140	70	30
Concrete	1000 SY	240	150	72
Gravel	1000 SY	85	50	22
Walks				
Asphalt	1000 SF	34	23	12
Concrete	1000 SF	44	30	15
Pipe culverts (includes concrete headwalls) (No excavation or backfill)				
24" and smaller	LF	0.56	0.34	0.18
26" to 45"	LF	0.95	0.58	0.30
48" to 72"	LF	1.50	0.93	0.48
Chain link fence				
5' high	1000 LF	111	74	37
8' high	1000 LF	153	102	51

82.86

Figure 3-19. —Preliminary manpower estimating table.

man-day figure to obtain the estimated man-days required for the project.

Suppose, for example, that the project is the construction of 5000 lin ft of concrete highway 30 ft wide. The area here is 5000 x 30, or 150,000 sq ft, which is 150,000/9, or 16,700 sq yd. Suppose it is assumed that construction will proceed under average conditions. Under such conditions, the table shown in figure 3-19 indicates that 140 man-days are required for every 1000 sq yd of concrete highway. Man-day requirements for 16,700 sq yd, then, would equal the value of x in the equation 140:1000::x:16,700, or 2338 man-days.

Obviously the overall work element "construct 16,700 sq yd of concrete highway" contains a number of subelements, such as (for a new highway over rough country) clearing and grubbing, excavating and earth-moving, preparing base and subbase, setting forms, batching and mixing concrete, casting concrete, finishing concrete, curing concrete, stripping forms, and so on. A detailed manpower estimate would determine the man-day requirements for each of these work elements. The estimator refers to a detailed manpower estimating table like the one shown in figure 3-20.

Figure 3-21 shows a WORK ELEMENT SUMMARY SHEET on which the manpower requirements for each of the elements shown have been computed. For the man-days per unit production factors the estimator referred to the tables shown in Table 3-1 and Table 3-2. For machine excavation, footings and foundations, Table 3-1 shows, for 1000 cu yd, under favorable conditions 12 man-days, under average 25, under adverse 50. The estimator selected 40, a figure only a little better than adverse. He may have known that the ground was exceptionally hard, or that the available equipment was old and worn, or that there were some other adverse circumstances relating to the excavating.

For the machine backfill, Table 3-1 shows 6 man-days per 1000 cu yd under average conditions; you can see that the estimator selected this figure. For hand compaction he selected 0.30 man-days per cu yd, a figure just a little better than that given for average conditions in Table 3-1. For machine spreading of excess earth he selected 1.6 man-days per 1000 cu yd, a figure not quite as good as that given for favorable conditions in Table 3-1.

For forming and stripping the estimator selected 44 man-days per 1000 sfcs, the figure given for average conditions in Table 3-2. For placing reinforcing steel he again used the average-conditions figure: 10 man-days per ton. For placing, finishing, and curing the concrete he selected 0.75 man-days per cu yd, about the figure given for adverse conditions in Table 3-2. He may have known that the mixing and finishing equipment was in poor condition, or that the skill of the masons was below average.

Factor Affecting Manpower Production

Principal factors affecting manpower production are: weather conditions during the construction period, skill and experience of the crew, time allotted for completion of the job, size of the crew to be used, accessibility of the site, and types of material and equipment to be used. The influence of weather conditions, skill and experience of the crew, and accessibility of the site need not be explained.

The time allotted may be so short as to require a "rush" job, with crews working long hours and perhaps 7 days a week. A man's production per hour decreases sharply under these conditions. With regard to the size of the crew, if a work area is crowded men are likely to get into each other's way, to talk and visit instead of working, or to cause production to fall off in other ways. This, of course, causes the man-hours required for a job to rise.

Many examples of how type of material affects man-day requirements could be cited. For instance: some types of soil are easier to dig and spread than others; some types of rock are easier to quarry and crush than others; some form materials require less labor than others; and some types of sheet piling are easier to drive than others.

The effect of type of equipment, too, is easy to make out. If earth is to be hauled in 5-yard trucks, a certain number of drivers will be required. If it is to be hauled in 10-yard trucks, only half as many driver man-hours will be required for the same amount of haul output. Similarly, more man-hours will be required for

SITE PREPARATION – CLEARING AND GRUBBING

WORK ELEMENT DESCRIPTION	UNIT	MAN-DAYS PER UNIT		
		ADVERSE CONDITION	AVERAGE CONDITION	FAVORABLE CONDITION
Clearing and grubbing by hand:				
Cutting trees and brush	1000 SY	7.0	4.8	2.0
Piling and burning	1000 SY	1.7	1.2	0.5
Digging and blasting stumps	each	0.3	0.2	0.1
Cutting large trees	each	0.6	0.4	0.2
Clearing and grubbing with equipment:				
Clearing trees and brush	1000 SY	0.7	0.4	0.2
Rooting out stumps	each	0.2	0.1	0.05
Loading and hauling	1000 SY	2.8	1.6	0.8
Burning trees and brush	1000 SY	0.7	0.4	0.2
For quick estimates; [1] Clearing and grubbing:				
By hand	1000 SY	9.6	6.6	2.8
With equipment	1000 SY	2.2	1.3	0.65

Typical crew: Hand work – 1 crew leader, 4 to 8 men with brushhooks and axes, 1 to 2 men with portable chain saws.

Typical crew: With equipment – 1 crew leader, 1 bulldozer operator, 2 to 5 men with chain saw and axes cutting and trimming large trees.

Typical crew: Burning – 2 to 5 men.

Note: Most stumps can be rooted out with a bulldozer unless the ground is very hard. Brush should not be burned until it has dried for several weeks. Old tires burned with the brush pile help to keep the fire going.

[1] Based on burning brush and trees at site, and 1 large tree per 1000 SY.

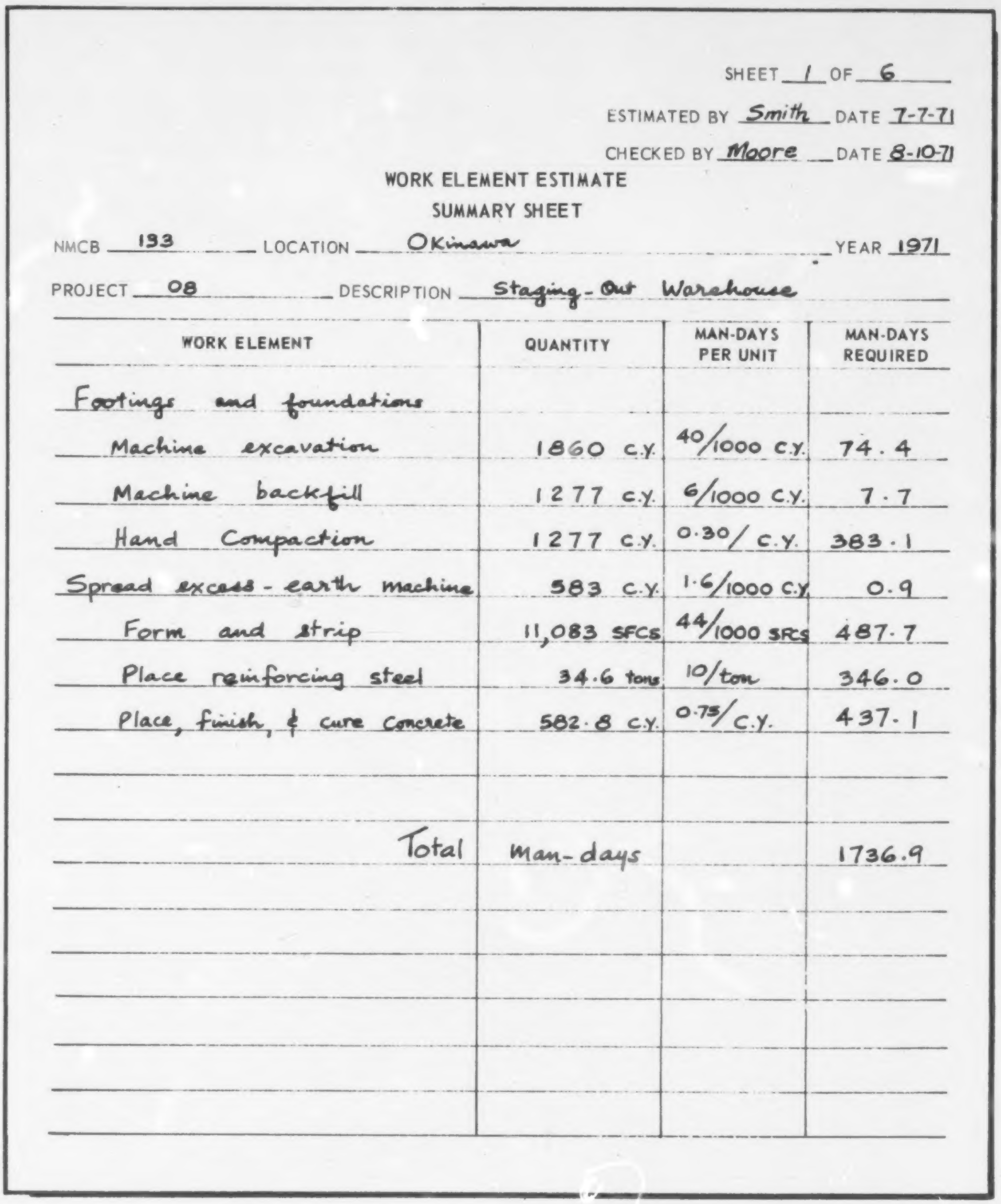
82.87

Figure 3-20. —Detailed manpower estimating table.

concrete placement by wheelbarrow than would be required for placement by bucket-and-crane.

CONSTRUCTION SCHEDULING

A schedule is a written plan for carrying out a project, indicating the time when each operation is to begin and the time when it should be completed. Scheduling is used to plan the sequence of projects on a deployment, and also the sequence of operations on each project. The schedule is the end product of all prior analysis and planning, and when implemented efficiently will ensure completion of the work at a specified time. However, it must be recognized that the schedule is only as accurate as the estimate from which it is developed.



SHEET 1 OF 6

ESTIMATED BY Smith DATE 7-7-71

CHECKED BY Moore DATE 8-10-71

WORK ELEMENT ESTIMATE
SUMMARY SHEET

NMCB 133 LOCATION Okinawa YEAR 1971

PROJECT 08 DESCRIPTION Staging-Out Warehouse

WORK ELEMENT	QUANTITY	MAN-DAYS PER UNIT	MAN-DAYS REQUIRED
Footings and foundations			
Machine excavation	1860 c.y.	40/1000 c.y.	74.4
Machine backfill	1277 c.y.	6/1000 c.y.	7.7
Hand Compaction	1277 c.y.	0.30/c.y.	383.1
Spread excess-earth machine	583 c.y.	1.6/1000 c.y.	0.9
Form and strip	11,083 SFCS	44/1000 SFCS	487.7
Place reinforcing steel	34.6 tons	10/ton	346.0
Place, finish, & cure Concrete	582.8 c.y.	0.75/c.y.	437.1
Total	Man-days		1736.9

82.88

Figure 3-21. –Work element summary sheet with manpower requirements computed.

Table 3-1.—Excavation for Footings and Foundations

WORK ELEMENT DESCRIPTION	UNIT	MAN-DAYS PER UNIT		
		ADVERSE CONDITION	AVERAGE CONDITION	FAVORABLE CONDITION
Machine evcavation for footings and foundations:				
Excavation [1]	1000 CY	50	25	12
Load excess earth	1000 CY	9.0	4.5	2.0
Haul excess earth	1000 yd miles	5.2	3.1	1.4
Spread spoil pile	1000 CY	2.1	1.4	0.7
Spread excess earth	1000 CY	4.5	3.0	1.5
Backfill	1000 CY	9	6	3
Compaction	1000 CY	12	8	4
Hand excavation for footings and foundations:				
Excavation	CY	1.2	0.7	0.3
Load excess earth	CY	0.8	0.4	0.2
Spread excess earth	CY	0.18	0.12	0.06
Backfill	CY	0.35	0.20	0.10
Compaction	CY	0.55	0.35	0.15
For quick estimates for excavating footings and foundations: [2]				
Machine excavation, complete	1000 CY	72	38	18
Hand excavation, complete	CY	2.1	1.0	0.5

Typical crew: Machine work – 1 crew leader, 2 men on excavating equipment, 2 to 6 trucks with operators, 1 man on equipment spreading and backfilling, 1 man on compacting equipment.

Typical crew: Hand work – 1 crew leader, 2 to 10 men excavating, loading and/or spreading excess dirt, backfilling and tamping.

[1] Includes trimming and fine grading.

[2] Includes removal and disposal of excess dirt, backfilling, and compaction.

82.89

USES OF A CONSTRUCTION SCHEDULE

The schedule serves as an operational guide for all managerial and supervisory personnel. Without such an instrument, coordination and teamwork would be very difficult to achieve. If fully understood, the schedule can be utilized before, during, and after construction.

Before Construction

Before work actually begins, the schedule ensures that the person in charge has some idea of the time required for construction. It shows clearly the sequence in which men, materials, and equipment are required, thus allowing one job to be integrated with another, and ensuring

Table 3-2.–Concrete Footings and Foundations

WORK ELEMENT DESCRIPTION	UNIT	MAN-DAYS PER UNIT		
		ADVERSE CONDITION	AVERAGE CONDITION	FAVORABLE CONDITION
Erect and strip forms	1000 SFCS*	70	44	22
Place reinforcing	Ton	16	10	5
Place, finish, and cure concrete	CY	0.7	0.4	0.2
For quick estimate: Concrete footing and foundation, complete	CY	3.4	2.0	0.8

Typical crew: 1 crew leader, 3 men erecting and stripping forms, 3 men placing reinforcing steel, and 4 men placing, spading, vibrating and finishing concrete.

* Square feet of contact surface.

82.90

maximum utilization of the constructing unit's capability.

During Construction

During construction, the schedule serves as a logical basis upon which to issue orders to subordinates. It ensures that equipment is not tied up longer than necessary, and that large numbers of troops are not brought on the job before they can be employed efficiently. Such a situation is not only wasteful, but is quickly interpreted as lack of organization, and will have an extremely adverse effect on morale. The schedule enables the officer in charge to prepare checklists to see exactly what jobs should be in operation at a given time. This permits more intelligent top level supervision than merely assuming "everyone is working, so everything must be all right." The schedule is a means of ensuring that material is not produced or delivered long before it is required, that storage facilities are utilized efficiently, and that effort is not expended needlessly in rehandling.

When field changes occur or production is slower than scheduled, the schedule will serve as a basis by which supervisors can evaluate these effects upon related work items. Plans for various solutions which will cope with the changes in scheduled operations can thus be made in an efficient manner. Up-to-date actual progress, plotted upon the schedule at regular and frequent intervals, reveals work items that are falling behind schedule in time to apply corrective action. The schedule also serves as the basis for preparation of progress reports to higher command levels.

After Construction

When the project is completed, an analysis of the schedule will be useful in isolating information for future reference. Noting which items fell behind or were completed ahead of schedule will enable estimators to reevaluate the rates used in their estimate, and to modify them for future use based on this new experience.

ELEMENTS OF SCHEDULING

The elements used in scheduling work include the work item number, the item description, the unit of measurement (cu yd, sq yd, ton, each, etc.), the quantity of work to be performed, the relation of each item to the whole in terms of work to be performed (such as percentage of the total work required for each item), units of time to be used in the schedule, the starting date, the time required for each item, and the completion date. The elements used in scheduling equipment and manpower are similar to those used for work schedules, but in addition include the number of pieces of equipment and number of men.

PRINCIPLES OF SCHEDULING

The development of a schedule is governed by four principles which remain inflexible even though the type of schedule is changed.

SCHEDULED OPERATIONS CANNOT EXCEED THE CAPABILITY TO ACCOMPLISH THE WORK. For example, if only five bulldozers are available, the maximum possible number which can be scheduled at any given time cannot be greater than five.

SCHEDULED OPERATIONS MUST FOLLOW THE SEQUENCE OF WORK REQUIRED FOR THE PARTICULAR JOB. For instance, the same part of a road cannot be surfaced while the base course is being constructed, nor can a roof be put on a building before the foundation and walls are up.

These limitations may appear so obvious as to merit little attention, yet the most common errors in scheduling involve violations of these two principles. If a schedule is made which does not violate either of these principles it will be a workable schedule, but it will not necessarily be a good schedule. Two other principles must be observed to develop a good schedule.

CRITICAL ITEMS MUST BE SCHEDULED AS SOON AS POSSIBLE. Maximum speed of completion of a project is most frequently the aim in advanced base construction. This is usually achieved by scheduling those items which take longest, or upon which many other operations are based, to begin as early as possible.

SCHEDULING MUST ENSURE CONTINUITY OF WORK EFFORT. Maximum efficiency in accomplishing a particular work item is best achieved if the time for accomplishing that item is as continuous as possible. For example, a grader on a road job should not be required to change, during short periods, from fine grading to sloping ditches to some other type of work. This reduces the output, and requires more supervisory personnel. These last two principles are often in opposition to one another and a balance must be made between them to obtain the best schedule.

TYPES OF SCHEDULES

Work schedules are usually prepared for the deployment as a whole and for each project of the deployment. Manpower and equipment schedules are normally prepared at the same time, because the information they contain is required for preparation of the work schedules. The separate projects of a deployment are scheduled in the deployment schedule; the separate work elements of a project are scheduled in a project schedule.

A typical deployment work schedule is shown in figure 3-22. The deployment will accomplish three projects: the construction of 22 replacement housing units, the laying of 12,600 lin ft of POL (petroleum oil lubricant) system, and the construction of 28,000 sq yd of road. It is estimated that, of the total work time allotted, 58.7 percent will be required for the replacement housing, 23.9 percent for the POL system, and 17.4 percent for the roads.

Project 1 will begin in March and end in October; project 2 will begin in April and end in October; and project 3 will begin in March and end in July. The estimated percentage of completion of each project for each month is as shown. These monthly figures are used to determine the estimated percentage of completion of the total project (deployment) shown at the bottom of the page. For example: in May, 34 percent of 58.7 percent, 18 percent of 23.9 percent, and 58 percent of 17.4 percent of the work will be accomplished. This amounts to 34 percent of the total work.

DEPLOYMENT WORK SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 1971 PREPARED 1-4-71 BY G. SMITH

PROJECT NO.	DESCRIPTION	UNIT	QUANTITY	WEIGHTED VALUE [1]	MONTHLY PRODUCTION – EST. AND ACT.							
					MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT
1	REPLACEMENT HOUSING	UNITS	22	58.7	10	25	34	43	52	66	85	100
2	POL SYSTEM	LF	12,600	23.9		2	18	39	58	80	91	100
3	ROADS	SY	28,000	17.4	8	31	58	75	100			
	TOTAL PROJECT			100.0	7	21	34	48	62	76	89	100

[1] WEIGHTED VALUE IS THE PERCENTAGE OF THE TOTAL MAN-DAYS ALLOCATED TO EACH PROJECT.

82.91

Figure 3-22. —Deployment work schedule.

Figure 3-23 shows the work schedule for one of the projects shown in figure 3-22. Figure 3-24 shows the deployment manpower schedule for 1 month of the deployment. The total man-days per month figure at the bottom is simply the sum of the total men per day full-day figures, plus half the sum of the total men per half-day figures. Figure 3-25 shows a one-month manpower schedule for one of the projects shown in figure 3-24.

Figure 3-26 shows the equipment schedule for the deployment. The interval during which each item of equipment will be required is indicated by a BAR at the right; for this reason, this type of schedule is called a BAR CHART. In figure 3-27, a similar bar chart shows the 1-month equipment schedule for one of the projects. Figure 3-28 shows a simple tabular type of project work schedule.

TECHNIQUES OF SCHEDULING

In scheduling a project, the first procedure is to list the work elements. Next, determine the construction sequences; obviously, excavating must come before foundation placement, wall construction before the installation of finish door and window frames, subbase and base preparation before paving, and so on. The starting date for the project is, of course, the starting date for the work element which is first in construction sequence.

The time required for each work element is determined by dividing the estimated man-days required by the number of men expected to be assigned to constructing that element. Each work element is scheduled in its proper construction sequence, showing starting and completion dates. Often, of course, it is not economical to wait until one element is finished before starting another. For example: concrete

PROJECT WORK SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 1971 PREPARED 1-4-71 BY G. SMITH
PROJECT -- POL SYSTEM

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	WEIGHTED VALUE	MONTHLY PRODUCTION – EST. AND ACT.							
					MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT
2A11	TRENCHING, DITCHING, & BACKFILLING	CY	2,200	9.1		10	27	44	61	78	95	100
2M2	INSTALL VALVES	EACH	25	0.9					15	50	80	100
2M4	CONSTRUCTION VALVE PITS	EACH	10	10.9			10	40	65	90	100	
2M13	INSTALL 12" PIPE	LF	12,600	58.2			20	39	58	77	95	100
2R9	PUMP HOUSE	EACH	1	15.4			15	40	65	85	100	
2Q3	WORK NOT COVERED ABOVE	L/S	1	5.5		5	20	40	55	70	90	100
	TOTAL PROJECT			100.0		1	18	39	60	79	96	100

82.92

Figure 3-23. —Project work schedule.

foundations can be started at one end of a building while excavating is still going on at the other end, or paving can begin at one end of a road while grading is still going on at the other.

PROGRESS CONTROL

Progress control is exercised by:

1. Measuring actual production against planned production.
2. Determining causes of discrepancies, if there are any.
3. Taking remedial action to correct deficiencies in production and to balance activities in order to attain overall objectives.

Reporting Progress

Work accomplished should be reported on daily labor reports. However, in some types of work, it is more convenient to report work quantities as portions are completed, rather than to attempt to report partial completion of portions. For example: if 2000 square feet of contact surface (sfcs) wall forms,are required for a section of concrete wall, it is difficult to estimate partial progress of the formwork, and no report is usually made until it is completed, ready for concrete placing.

Items suitable for daily reporting are those which may reasonably be expected to show a fairly steady production rate per man-hour, such as laying concrete block, placing concrete or asphalt paving, or the excavating and/or hauling of large quantities of cut and fill. For such items, daily reports provide a continuous, running check on progress.

A daily report should show the man-hours expended on each work element. Preparation of weekly or monthly reports is accomplished by recording daily reports in ledger form and totaling for a week or month.

Monthly progress reports are usually made in narrative form, with a progress chart (explained

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DEPLOYMENT MANPOWER SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 1971 PREPARED 1-4-71 BY G. SMITH
PROJECT -- POL SYSTEM

PR. NO.	DESCRIPTION		JULY																														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	REPLACEMENT HOUSING	E	47	47	49	☒	49	☒	49	41	48	48	48	50	☒	46	54	54	50	54	54	☒	54	47	47	43	50	47	☒	47	47	42	42
		A																															
2	POL SYSTEM	E	50	50	48	☒	48	☒	48	56	49	49	49	47	☒	51	43	43	47	43	43	☒	43	50	50	54	47	50	☒	50	50	55	55
		A																															
3	ROADS	E	40	40	40	☒	40	☒	40	40	40	40	40	40	☒	40	40	40	40	40	40	☒	40	40	40	40	40	40	☒	40	40	40	40
		A																															
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		A																															
		E																															
		A																															
		E																															
		A																															
TOTAL MEN PER DAY		E	137	137	137	☒	137	☒	137	137	137	137	137	137	☒	137	137	137	137	137	137	☒	137	137	137	137	137	137	☒	137	137	137	137
		A																															
TOTAL MAN-DAYS PER MONTH		E	3288																														
		A																															

☒ DENOTES SUNDAYS AND HOLIDAYS WHEN NO WORK IS SCHEDULED.

⧄ DENOTES SATURDAYS WHEN HALF DAY'S WORK IS SCHEDULED.

Figure 3-24. –Deployment manpower schedule. 82.93

PROJECT MANPOWER SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 1971 PREPARED 1-4-71 BY G. SMITH
PROJECT -- POL SYSTEM

IT. NO.	DESCRIPTION		JULY																														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2A11	TRENCHING, DITCHING, BACKFILL	E	2	2	2	☒	2	☒	2	2	2	2	2	2	☒	2	2	2	2	2	2	☒	7	7	7	7	7	7	☒	7	7	7	7
		A																															
2M2	INSTALL VALVES	E			2	☒	2	☒	2	2					☒							☒	2	2	2				☒				
		A																															
2M4	CONSTRUCT VALVE PITS	E	6	6	6	☒	6	☒	6	10	5	5	5	6	☒	10	6	6	10	6	6	☒	6	6	10	5	5	5	☒	5	5	10	10
		A																															
2M13	INSTALL 12 PIPE	E	26	26	26	☒	26	☒	26	26	26	26	26	26	☒	26	26	26	26	26	26	☒	19	26	22	33	23	26	☒	26	26	26	26
		A																															
2R9	PUMP HOUSE	E	12	12	12	☒	12	☒	12	12	12	12	12	9	☒	9	9	9	9	9	9	☒	7	7	7	7	10	10	☒	10	10	10	10
		A																															
2Q3	WORK NOT COVERED ABOVE	E	4	4		☒		☒		4	4	4	4	4	☒	4						☒	2	2	2	2	2	2	☒	2	2	2	2
		A																															
		E																															
		A																															
TOTAL MEN PER DAY		E	50	50	48	☒	48	☒	48	56	49	49	49	47	☒	51	43	43	47	43	43	☒	43	50	50	54	47	50	☒	50	50	55	55
		A																															
TOTAL MAN-DAYS PER MONTH		E	1174																														
		A																															

Figure 3-25. –Project manpower schedule. 82.94

DEPLOYMENT EQUIPMENT SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 1971 PREPARED 1-4-71 BY G. SMITH

PROJECT NO. & DESCRIP.	EQUIPMENT	NO. REQ.	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT
1 REPLACEM'T HOUSING	AIR COMPRESSOR, 210 CFM	1					—	—	—	—
	BULLDOZER, 113/130 DBHP	1	—							
	CRAWLER CRANE, 45 TON	1			—	—	—	—		
	MORTOR MIXER, 6 CF	2		—	—	—	—	—		
	MOTOR GRADER, 12" BLADE	1	—							
	TRUCKS, 2 TON, STAKE	3	—	—	—	—	—	—		
2 POL SYSTEM	BULLDOZER, 113/130 DBHP	1			—	—	—	—	—	—
	MORTOR MIXER, 6 CF	1			—	—				
	MOTOR CRANE, 20 TON	2			—	—	—	—	—	—
	TRENCHING MACHINE	1		—	—	—	—	—		
3 ROADS	ASPHALT DISTRIBUTOR, 24" WIDTH	1			—	—	—			
	ASPHALT FINISHER, 10'-14' WIDTH	1			—	—	—			
	ASPHALT PLANT, COMPLETE, 100 TON	1			—	—	—			
	BULLDOZER, 110/113 DBHP	2	—	—	—					
	MOTOR GRADER, 12' BLADE	1		—	—					
	SCRAPERS, SELF-PROPELLED, 12 CY	3	—	—	—					
	TANDEM ROLLER, SELF-PROPELLED	1			—	—	—			
	TRACTOR, PUSHER, 113/130 DBHP	1	—	—	—					
	TRUCKS, 10 TON, DUMP	3			—	—	—			
	VIBRATING COMPACTOR	1	—	—	—					
ALL PROJECTS	CONCRETE BATCH PLANT, COMPLETE	1		—	—	—	—	—		
	TRANSIT-MIX TRUCKS, 5½ CY	3		—	—	—	—	—		

82.95

Figure 3-26. —Deployment equipment schedule.

later) included in the report. Major problems affecting progress should be described, and any unusual construction methods should be reported in detail, with sketches included if necessary. If progress is behind schedule, the report should describe what measures are being taken to bring it back on schedule, or explain why the completion date cannot be met and what extension of time is needed for completion.

Charting Progress

A common way of charting progress is to insert percentages of actual work completed in spaces left adjacent to the figures for estimated completion percentages on work schedules.

THE CRITICAL PATH METHOD

In recent years, a network analysis system of project planning, scheduling, and control, called the CRITICAL PATH METHOD (CPM), has come into existence and widespread use in the construction industry. The object of CPM is to combine all the information relevant to the planning and scheduling of project functions into a single master plan—a plan that coordinates all of the many different efforts required to accomplish a single objective, that shows the interrelationships of all of these efforts, that shows which efforts are critical to timely completion, and hence promotes the most efficient use of equipment and manpower.

The Critical Path Method of scheduling was one of the outgrowths of the Program Evalua-

PROJECT EQUIPMENT SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 1971 PREPARED 1-4-71 BY G. SMITH
PROJECT -- POL SYSTEM

ITEM NO. DESCRIPTI	EQUIPMENT	NO. REQ.	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT
2A11 TRENCH & BF	TRENCHING MACHINE	1		—	—	—	—	—	—	
	BULLDOZER, 130 DBHP	1			—	—	—	—	—	—
2M2 INST VALVES	MOTOR CRANE, 20 TON	1								
			Work in conjunction with 12" Pipe							
2M13 INST 12" PIPE	MOTOR CRANE, 20 TON	2			—	—	—	—	—	—
	BULLDOZER, 130 DBHP	1		—	—					
2R9 PUMP HOUSE	MOTOR CRANE, 20 TON	1				—				
	MORTAR MIXER, 6 CF	1			—	—				

82.96

Figure 3-27. —Project equipment schedule.

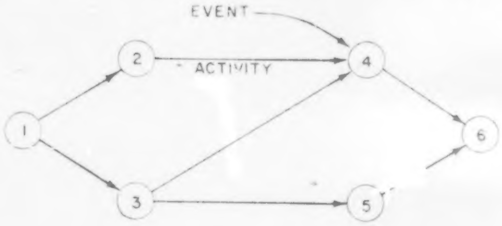
PROJECT WORK SCHEDULE

NMCB 40 LOCATION -- DIEGO GARCIA YEAR -- 1971 PREPARED 1-4-71 BY G. SMITH
PROJECT -- POL SYSTEM

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	WEIGHTED VALUE	ESTIMATED		ACTUAL	
					START	FINISH	START	FINISH
2A11	TRENCHING, DITCHING, & BACKFILLING	CY	2,200	9.1	4-16-71	10-18-71		
2M2	INSTALL VALVES	EACH	25	0.9	7-16-71	10-16-71		
2M4	CONSTRUCT VALVE PITS	EACH	10	10.9	5-14-71	9-20-71		
2M13	INSTALL 12" PIPE	LF	12,600	58.2	4-30-71	10-16-71		
2R9	PUMP HOUSE	EACH	1	15.4	5-14-71	9-29-71		
2Q3	WORK NOT COVERED ABOVE	L/S	1	5.5	4-16-71	10-18-71		
	TOTAL PROJECT			100.0	4-16-71	10-18-71		

82.97

Figure 3-28. —Project work schedule.



117.308X
Figure 3-29. —Activities and events.

tion Review Technique (PERT) developed in the Special Projects Office, BuWeps, Navy Department and a project planning and scheduling technique based on network analysis called Critical Path Planning and Scheduling (CPPS).

While CPM has been most widely applied in the construction field, other possible applications are almost unlimited. A shop supervisor, for instance, may often find CPM useful in planning work to obtain most economical manpower utilization.

There is a lot to know about CPM and you may not find all the information you need on the subject in this training manual. Sufficient coverage is provided, however, to assist you in preparing arrow diagrams, interpreting critical path schedules drawn up for jobs under your supervision, and in developing critical path schedules for future construction projects.

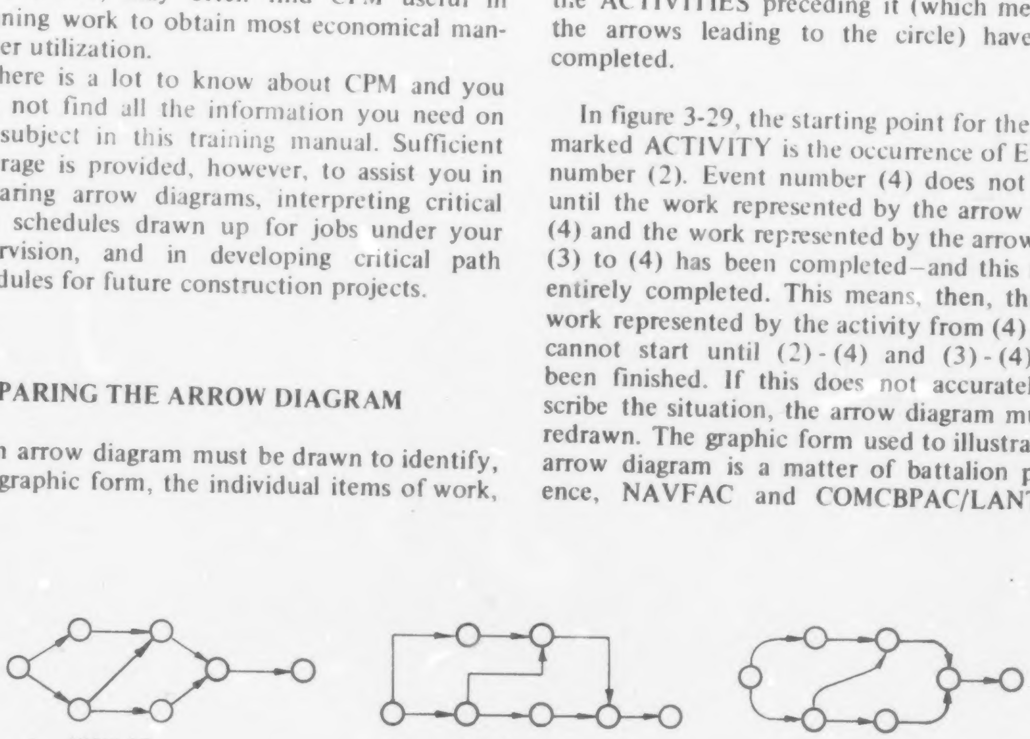
PREPARING THE ARROW DIAGRAM

An arrow diagram must be drawn to identify, in a graphic form, the individual items of work, services or tasks–referred to in CPM as ACTIVITIES–that are involved in constructing the project. Also, of equal importance, the arrow diagram must show how each ACTIVITY depends upon others during the sequence of construction.

In substance, the arrow diagram graphically describes the sequence of ACTIVITIES as well as the interrelationship of ACTIVITIES within the project. In addition to the term "arrow diagram", this graphic technique is sometimes referred to as being an ARROW NETWORK, a DEPENDENCY DIAGRAM, a DEPENDENCY NETWORK, or a LOGIC NETWORK.

In an arrow diagram, both arrows and circles are used to describe the sequence of work. An arrow represents an ACTIVITY, and a circle represents an EVENT. An EVENT is the starting point of an ACTIVITY and occurs only when all the ACTIVITIES preceding it (which means all the arrows leading to the circle) have been completed.

In figure 3-29, the starting point for the arrow marked ACTIVITY is the occurrence of EVENT number (2). Event number (4) does not occur until the work represented by the arrow (2) to (4) and the work represented by the arrow from (3) to (4) has been completed–and this means entirely completed. This means, then, that the work represented by the activity from (4) to (6) cannot start until (2)-(4) and (3)-(4) have been finished. If this does not accurately describe the situation, the arrow diagram must be redrawn. The graphic form used to illustrate the arrow diagram is a matter of battalion preference, NAVFAC and COMCBPAC/LANT are


ANGULAR PARALLEL FREE FORM

117.309X
Figure 3-30. —Graphic forms used in arrow diagramming.

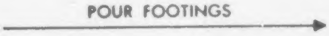
somewhat liberal about the form or specific technique used. Three of the more common graphic forms used in arrow diagramming are shown in figure 3-30.

Because everything that happens in CPM is based on dependency situations (i.e., one activity dependent upon others), the arrow diagram must be a meaningful description of the project. If it is not, less than satisfactory results will be obtained from CPM. In almost every case of difficulties or dissatisfaction with CPM, the cause can be traced to a faulty or unrealistic arrow diagram. Everything in an arrow diagram has significant meaning, and for this reason the basic principles must be understood and applied completely.

Principle Number 1

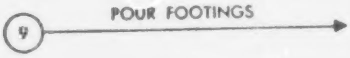
The first principle of arrow diagram development that must be understood is that *everything in the diagram has meaning.* Within this principle, the following rules *must* be learned and applied.

1. Every arrow represents an item of work and is referred to as an ACTIVITY.



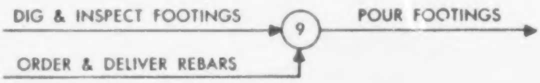
117.310X

2. An EVENT is the starting point of an ACTIVITY, shown as a circle.



117.311X

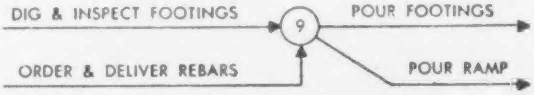
3. An ACTIVITY depends upon and cannot begin until the completion of all preceding ACTIVITIES.



117.312X

As illustrated above, POUR FOOTINGS depends upon the completion of DIG & INSPECT FOOTINGS and ORDER & DELIVER REBARS.

4. All activities that start with the same event depend upon and cannot begin until the completion of *all* activities that enter that event.



117.313X

In the case illustrated above, POUR FOOTINGS and POUR RAMP depend upon the completion of the two activities that enter their common starting event. In other words, it is impossible to POUR FOOTINGS or to POUR RAMP until DIG & INSPECT FOOTINGS, and ORDER & DELIVER REBARS have both been completed. The diagram indicates that all the footings (not just some) must be dug and inspected, and all necessary rebars must be on hand, before either of the two activities starting with event (9) can begin.

In figure 3-31, all three activities that start with event (10) must wait until all activities that enter event (10) have been entirely completed. None of the three can possibly start until both OBTAIN PERMITS and PRELIMINARY SURVEY have been finished. If one of the three

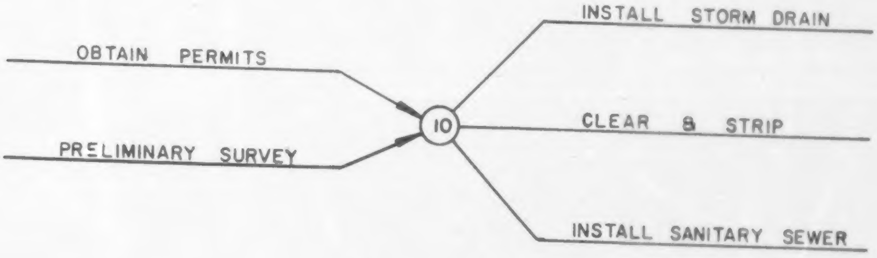

OBTAIN PERMITS
PRELIMINARY SURVEY
10
INSTALL STORM DRAIN
CLEAR & STRIP
INSTALL SANITARY SEWER

Figure 3-31. —Three activities starting at a common event.

117.314X

leaving (10) does not depend upon the completion of *both* those entering (10), the arrow diagram is misdrawn and the schedules produced from it will not be realistic.

Principle Number 2

A second principle is that *an activity has a single definite starting point and a single definite ending point.* Placing an arrow in a diagram must satisfy two basic questions:

1. "What activities must be completed before this one can start?" This indicates the event from which to start the activity.
2. "What activities cannot be started if this one is not completed?" This indicates into which event the activity should enter.

Suppose, for example, the following arrow diagram (fig. 3-32) had been drawn.

As shown, excavating for the footings and pads for the Boiler Room is the first ACTIVITY, followed by placing the concrete footings and pads. At EVENT (3) and as a result of the completion of the previous activities, several independent work items then can commence.

Suppose, however, that it is desired to add an activity to indicate delivery of concrete block for the walls of the boiler room. The first question asked about this new activity should be, "What must be finished before the block can be ordered and delivered?" Actually, there is nothing in the diagram that—if not accomplished—would hold up the ordering and delivery of block. The starting point for this ACTIVITY would then be EVENT (1).

The second question to be asked about the new activity is, "What cannot proceed until this activity is completed?" The answer is, of course, BLOCK WALLS, BOILER ROOM. The termination point for this new activity then is EVENT (4) and the results of the analysis described above would appear as illustrated in figure 3-33.

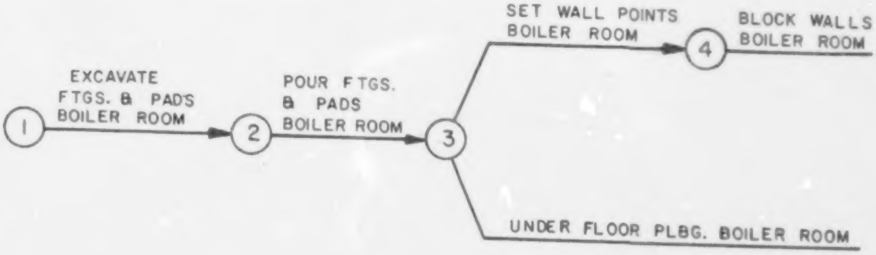
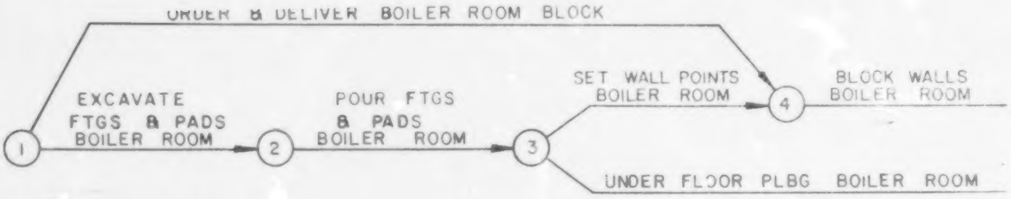

1
EXCAVATE FTGS. & PADS BOILER ROOM
2
POUR FTGS. & PADS BOILER ROOM
3
SET WALL POINTS BOILER ROOM
4
BLOCK WALLS BOILER ROOM
UNDER FLOOR PLBG. BOILER ROOM

Figure 3-32. —Diagram development.

117.315X

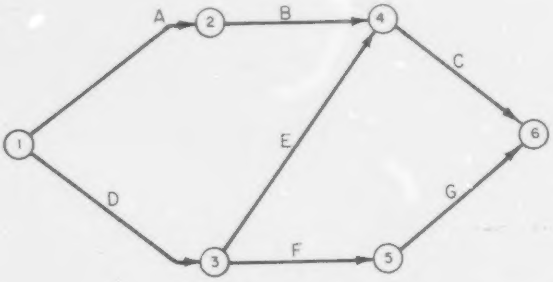

ORDER & DELIVER BOILER ROOM BLOCK
EXCAVATE FTGS & PADS BOILER ROOM
POUR FTGS & PADS BOILER ROOM
SET WALL POINTS BOILER ROOM
BLOCK WALLS BOILER ROOM
UNDER FLOOR PLBG BOILER ROOM
1
2
3
4

117.316X

Figure 3-33. –Adding an activity.

Principle Number 3

A third principle is that the arrow diagram does not describe time relationships, but rather dependency relationships. *Generally*, the arrow diagram is not drawn on a time scale. That is, the length and direction of an activity arrow has no relationship to the amount of time required to accomplish the work represented by it. Likewise, two activities starting with the same event do not necessarily occur at the same time. In figure 3-34, the only thing that is actually known about ACTIVITY A & D is that they are independent. They may or may not go on at the same time. The time that an ACTIVITY takes place is decided in the Scheduling Phase, not by the arrow diagram. The arrow diagram merely defines the dependency situations that exist. In the illustration involving the concrete block for the boiler room walls, for example, the activity ORDER & DELIVERY BOILER ROOM BLOCK starts with event (1), as does EXCAVATE FOOTINGS & PADS, etc. This does not mean that both activities must be conducted at the same time. They might, but probably won't. The only thing indicated is that these two activities are independent.



117.317X

Figure 3-34. –Dependency relationships.

Principle Number 4

It is very important to realize that the arrow diagram is hardly ever drawn by a single person. Because the accomplishment of the schedule produced from the arrow diagram is affected by a large number of people, all persons who *have anything to do with the project must be consulted when creating the arrow diagram*. All crew leaders should be asked to review the arrow diagram carefully to make certain that the activities pertaining to their work are accurately and realistically described. This principle applies also and equally to the production of duration estimates for the activities.

Other Rules and Conventions

Notice in the illustrations thus far, that the events (sometimes referred to as nodes) are all numbered. This makes it possible to uniquely identify an activity–and its position in the diagram. An ACTIVITY is identified by using the event number at its tail (called the activity's "I") and the event number at its head (called the activity's "J"). In the boiler room illustration, POUR FOOTINGS & PADS-BOILER ROOM could be referred to as ACTIVITY (2) - (3) and identified in that fashion.

So that an activity can be uniquely identified by its "I" and "J" numbers, a rule must be established and observed in the creation of the arrow diagram. The rule can be stated as follows:

> "NOT MORE THAN ONE ACTIVITY MAY HAVE THE SAME 'I' AND THE SAME 'J'."

In order to observe this rule, it is sometimes necessary to use a "connector" type of activity that doesn't really represent work, but merely helps to observe the rule stated above. This type of activity is usually referred to as a "dummy". This special activity is drawn as a dotted line and indicates that no work is involved in that activity.

Figure 3-35 illustrates this rule and the use of the dotted-line (dummy) activity. The dotted-line activity represents the dummy and involves no duration and no cost. It serves only as a dependency connector or sequence indicator.

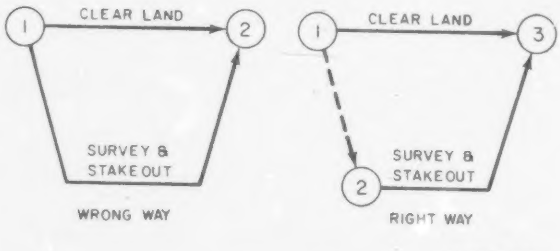
Dummies have purposes in addition to the one mentioned above, and will be discussed in more detail later.

If one plans to produce a schedule *by hand,* the numbering of the events must be watched closely. Extreme care must be taken to make sure of two things:

1. Every number must be used, and
2. The number at the tail of any arrow must be less than the number at the head of that arrow.

It is always wise to refrain from numbering the diagram until it has been completed, reviewed and approved.

Another rule governing the creation of the arrow diagram is that a project will have only one starting event and only one ending event. When nothing must be done prior to the start of an activity, the arrow representing that activity starts with the project's starting event. When nothing depends upon the accomplishment of an activity, its arrow ends with the project's ending event. One always knows, because of this rule, where an activity belongs in the network.



117.318X

Figure 3-35. —Activity identification.

It must be kept firmly in mind that restricting the arrow diagram to one starting event and one ending event, *does not at all limit the number of starting or ending activities.*

The arrow diagram is the single most important piece of input information and serious effort must be expended on its production. The arrow diagram makes up about 80% of the Planning Phase and even if only this is done, substantial benefits will be obtained from CPM.

The creation of a realistic, accurate, and meaningful arrow diagram requires a complete and detailed analysis of the job described. This disciplined approach to the planning of a job provides the planner with insights about the project unattainable in any way other than actually accomplishing it. The detailed investigation necessary to produce a good arrow diagram also pinpoints problem areas, allowing the planner sufficient time to make proper preparation prior to arriving at this point of construction.

The creation of a realistic arrow diagram requires that the project planner be intimately acquainted with the project and the organization accomplishing it. One can obtain assistance in the production of an arrow diagram, but one can never entirely divorce himself from the proceedings.

ARROW DIAGRAM CONSTRUCTION PROBLEMS

This section will be devoted to problems requiring the production of arrow diagrams. Before attempting to draw diagrams for the projects described later in this section, you would do well to review the previous section, particularly the pages in which the arrow diagram and the principles guiding its creation are discussed in detail. If CPM is to be used successfully, the arrow diagram upon which CPM is based must be properly drawn. For the arrow diagram to be properly drawn, the principles upon which its creation are based must be completely and thoroughly understood.

The major items to keep in mind when creating an arrow diagram are:

1. Everything in the arrow diagram has significant meaning.
2. An activity has a single definite starting point, and a single definite ending point.
3. The arrow diagram describes dependency relationships rather than time relationships.

Remember that when an arrow, representing an activity, is placed into the diagram, two questions are asked about it–

1. What activities must be completed before this one can start?
2. What activities cannot start until this one has been completed?

The answer to the first question determines the event that starts the activity, while the answer to the second question indicates at what event the activity ends.

PROBLEM 1

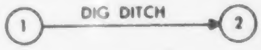
To illustrate the arrow diagram with an actual problem, suppose that it was desired to install a drainage ditch in the backyard of a house. Assume for this problem that only one man was going to work on this project. Draw a diagram for this one-man project including only the following activities:

1. DIG DITCH
2. PLACE GRAVEL IN BOTTOM OF DITCH
3. OBTAIN DRAINTILE
4. INSTALL DRAINTILE AND BACKFILL

Make the following assumptions about these activities:

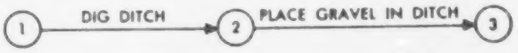
A. There is no need to order or deliver gravel. There is a supply in the driveway.
B. OBTAIN DRAINTILE does not require the effort of the one man doing this project. It is a "delivery" type activity.

The first activity possible in this project is DIG DITCH–so an activity indicating this would be drawn.



117.319X

After the ditch had been dug, the placing of the gravel would be next and the diagram would describe this as follows:



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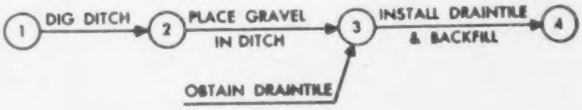
After the gravel is in, the draintile could be installed. However, in order for this to happen, the draintile must have been obtained. This means that the activity OBTAIN DRAINTILE must end at the beginning of INSTALL DRAINTILE AND BACKFILL. This will be at event (3) and the diagram would look like this:



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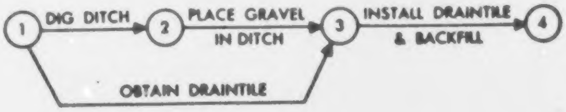
The question remaining is where does OBTAIN DRAINTILE start? One must further ask what activities must be accomplished before this one can start. It turns out that nothing need be done in order to start this activity and it thus starts with event (1). The completed solution is below.



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PROBLEM 2

To create a slightly more complicated problem, consider the situation that would exist if the work described in problem 1 had been performed in the street in front of the house rather than in the backyard.

If this were the case, it would be necessary to add to the list of activities given for 1, the following:

5. OBTAIN PERMIT TO BLOCK STREET
6. BLOCK STREET
7. OBTAIN TRENCHER
8. ORDER AND DELIVER PAVING MATERIAL
9. PAVE STREET

For this problem, the following assumptions are made in addition to those already mentioned in problem 1:

C. The permit is only necessary to block the street. There is no doubt that it will be obtained.
D. OBTAIN TRENCHER is a delivery type activity just as OBTAIN DRAINTILE was in problem 1.

The solution to this problem would start with the first activity that can take place. In this problem, four independent activities can be shown as starting the project. (See view A of fig. 3-36.) Which one goes where, is not at all important. In the beginning, it may appear that all four activities are expected to start or take place at the same time. *This is definitely not the case.* The person drawing the diagram must realize and remember at all times that the arrow diagram *does not describe time relationships* but rather only dependencies. This diagram, so far, states only that OBTAIN TRENCHER, OBTAIN PERMIT, OBTAIN DRAINTILE, and ORDER AND DELIVER PAVING MATERIAL are independent, that is, can start at any time whether other activities have started or not. "When" these activities take place will be determined in the scheduling phase.

The next item that can be placed into the diagram is BLOCK STREET. The only thing that must be done before this activity can start is OBTAIN PERMIT. This new activity then starts with event (2) as shown in view B of figure 3-36.

The assumption that obtaining the permit was only a formality makes it possible to show OBTAIN TRENCHER, OBTAIN DRAINTILE and the PAVING MATERIAL ACTIVITY as starting with event (1). If this assumption had not been made, a prudent decision would have been to start these activities at event (2) so as to avoid spending money without being sure of the results.

After the street had been blocked, DIG DITCH could start. However, because the ditch is to be dug through the pavement, the trencher would have to be on hand. The arrow diagram indicating this would appear as shown in view C of figure 3-36.

From this point until the final activity, the diagram would be constructed as it was for problem 1, as shown in view D of figure 3-36.

The final activity would be the repair to the damage caused by tearing up the street. In order to pave, however, the paving materials would have to be on hand. This situation is described by making the event that starts PAVE STREET (6), and making the same event the end point for ORDER AND DELIVER PAVING MATERIAL. The final solution to this problem is illustrated in view E of figure 3-36.

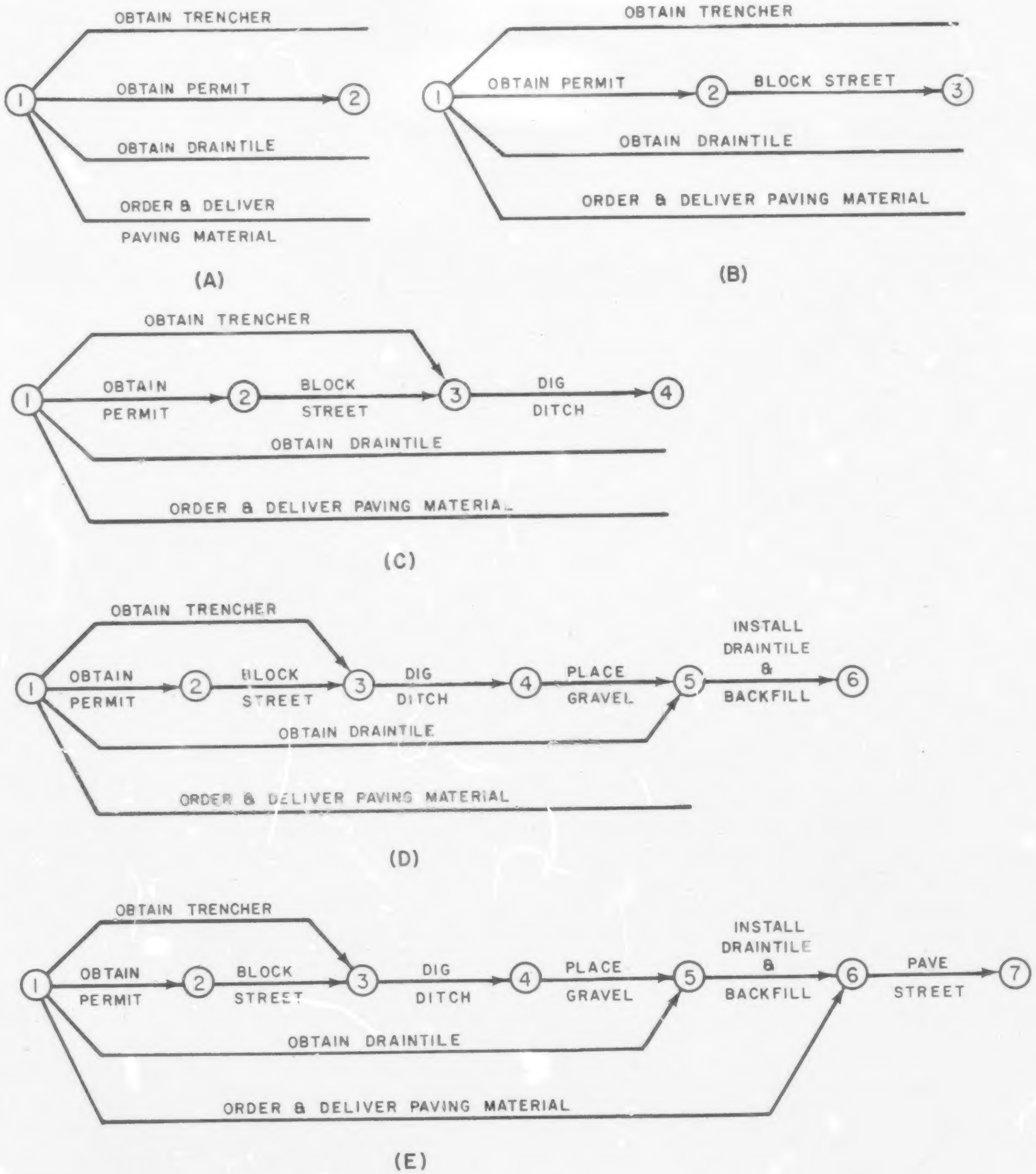
An important point to remember about arrow diagrams is that *the assumptions made about the activities are as important as the activities themselves.* They should always be written down, so as to be remembered.

PROBLEM 3

Create an arrow diagram for a reinforced concrete equipment foundation project to be built partially below ground level. Assume that all necessary tools, equipment and materials (including concrete) are on the job site, and that there is no limit to the number of workers. A rented backhoe is used to excavate. Use only the following activities:

1. LAY OUT AND EXCAVATE
2. FINE GRADE
3. PREFABRICATE FORMS
4. PREFABRICATE REBAR
5. SET FORMS
6. SET REBAR AND ANCHOR BOLTS
7. ADVISE AVAILABILITY OF BACKHOE
8. POUR CONCRETE

For this problem, assume that FINE GRADE must be done before the forms are set.

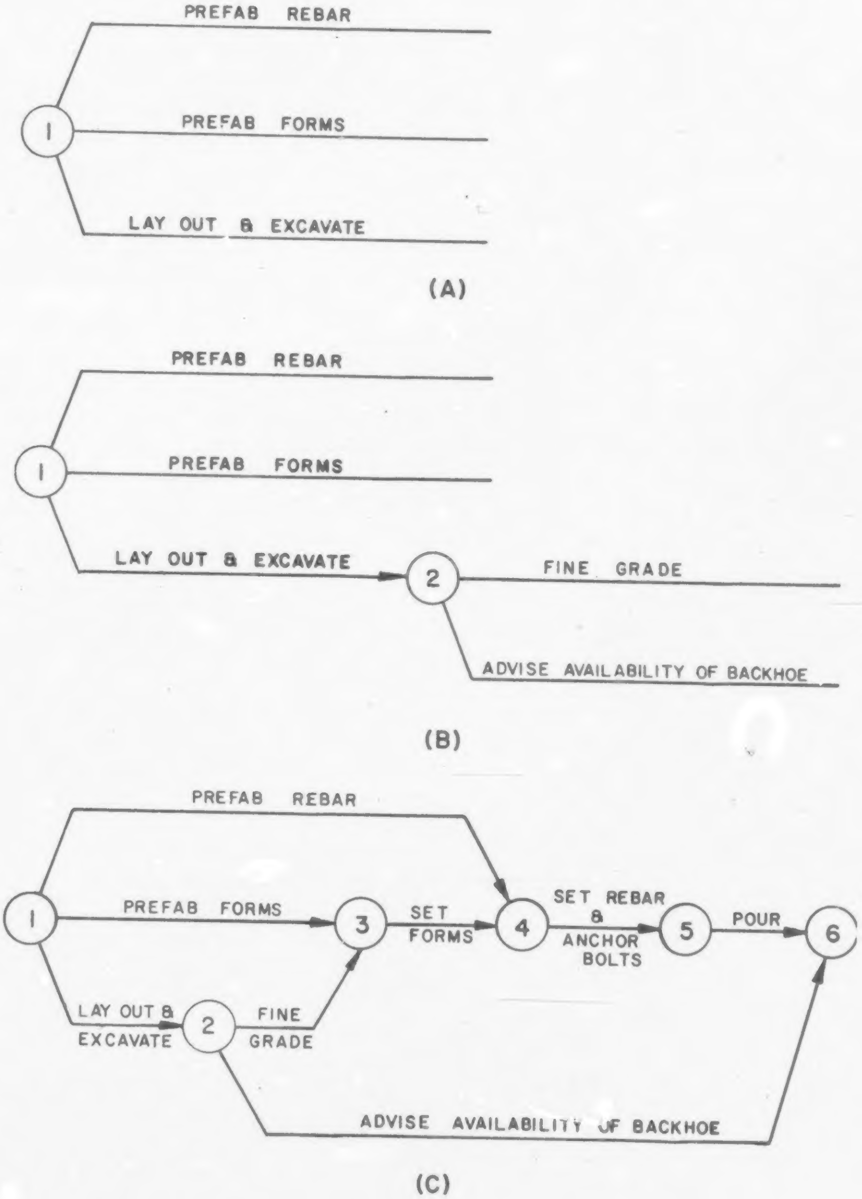

OBTAIN TRENCHER
1
OBTAIN PERMIT
2
OBTAIN DRAINTILE
ORDER & DELIVER
PAVING MATERIAL
(A)
OBTAIN TRENCHER
1
OBTAIN PERMIT
2
BLOCK STREET
3
OBTAIN DRAINTILE
ORDER & DELIVER PAVING MATERIAL
(B)
OBTAIN TRENCHER
1
OBTAIN
PERMIT
2
BLOCK
STREET
3
DIG
DITCH
4
OBTAIN DRAINTILE
ORDER & DELIVER PAVING MATERIAL
(C)
OBTAIN TRENCHER
1
OBTAIN
PERMIT
2
BLOCK
STREET
3
DIG
DITCH
4
PLACE
GRAVEL
5
INSTALL
DRAINTILE
&
BACKFILL
6
OBTAIN DRAINTILE
ORDER & DELIVER PAVING MATERIAL
(D)
OBTAIN TRENCHER
1
OBTAIN
PERMIT
2
BLOCK
STREET
3
DIG
DITCH
4
PLACE
GRAVEL
5
INSTALL
DRAINTILE
&
BACKFILL
6
PAVE
STREET
7
OBTAIN DRAINTILE
ORDER & DELIVER PAVING MATERIAL
(E)

117.323X

Figure 3-36. —Diagram development for problem 2.

One would start the arrow diagram with three independent activities as indicated in view A of figure 3-37. Remember that the diagram does not indicate that these three items go on at the same time. It only shows that they are not dependent on the completion of any other activities.

After the layout and excavation had been completed, two activities could be started. FINE GRADE would depend upon the completion of


PREFAB REBAR
1
PREFAB FORMS
LAY OUT & EXCAVATE
(A)
PREFAB REBAR
1
PREFAB FORMS
LAY OUT & EXCAVATE
2
FINE GRADE
ADVISE AVAILABILITY OF BACKHOE
(B)
PREFAB REBAR
1
PREFAB FORMS
3
SET FORMS
4
SET REBAR & ANCHOR BOLTS
5
POUR
6
LAY OUT & EXCAVATE
2
FINE GRADE
ADVISE AVAILABILITY OF BACKHOE
(C)

117.324X

Figure 3-37. —Diagram development for problem 3.

this activity, and, of course, the backhoe could not be returned until the completion of this phase of work. At this point the diagram would appear as indicated in view B of figure 3-37.

Again, the diagram is *not* stating that FINE GRADE and that ADVISE AVAILABILITY OF BACKHOE occur simultaneously, but rather that they both depend upon–cannot start until–the completion of LAY OUT AND EXCAVATE.

After FINE GRADE had been completed, and when PREFAB FORMS was finished, SET FORMS could start. At its conclusion, and after PREFAB REBAR had been completed, it would be possible to SET REBAR and ANCHOR BOLTS and then finally POUR. The final arrow diagram would look like view C of figure 3-37.

DUMMIES

Occasionally, it is necessary to use a "connector" type activity to indicate a dependency relationship without causing confusion. This type of activity, which does not represent work and which has a duration of zero, is called a DUMMY activity and is shown on the arrow diagram as a dotted line.

There are two reasons for using dummies. These two reasons can be illustrated by altering problem 3 above. Suppose that instead of having a single activity called SET REBAR AND ANCHOR BOLTS, it was desired to make two activities: one called SET REBAR and the other called SET ANCHOR BOLTS. Suppose that both depended upon PREFAB REBAR, and SET FORMS, and that both had to be completed before the POUR. The affected part of the diagram would appear as illustrated in view A of figure 3-38.

From a dependency point of view, there is nothing wrong with this kind of description. However, confusion results from having more than one activity with the same I - J numbers. It is not clear which is activity (4) - (5). Earlier in this chapter a rule was established to solve this problem. It was stated that *not more than one activity may have the same "I" and the same "J"*. So as not to break this rule, one of the two "non-unique" activities must be changed into two, one of which is a dummy. The affected part of the diagram would now appear as illustrated in view B of figure 3-38.

If view B of figure 3-38 is examined closely, the following points become clear:

1. Event (6) occurs when SET REBAR and SET ANCHOR BOLTS have been completed.
2. Since the DUMMY from (4) to (5) activity has zero duration, it is completed at the same point in time that event (4) occurs.
3. For this reason, event (5) occurs when SET FORMS is finished and PREFAB REBARS is finished, and SET ANCHOR BOLTS can start at this time.
4. This is exactly the same dependency statement that was made in the incorrect solution illustrated in view A of figure 3-38 in which two activities from (4) - (5) appeared.

The first reason for using a dummy then is to maintain the uniqueness of the I - J identification system.

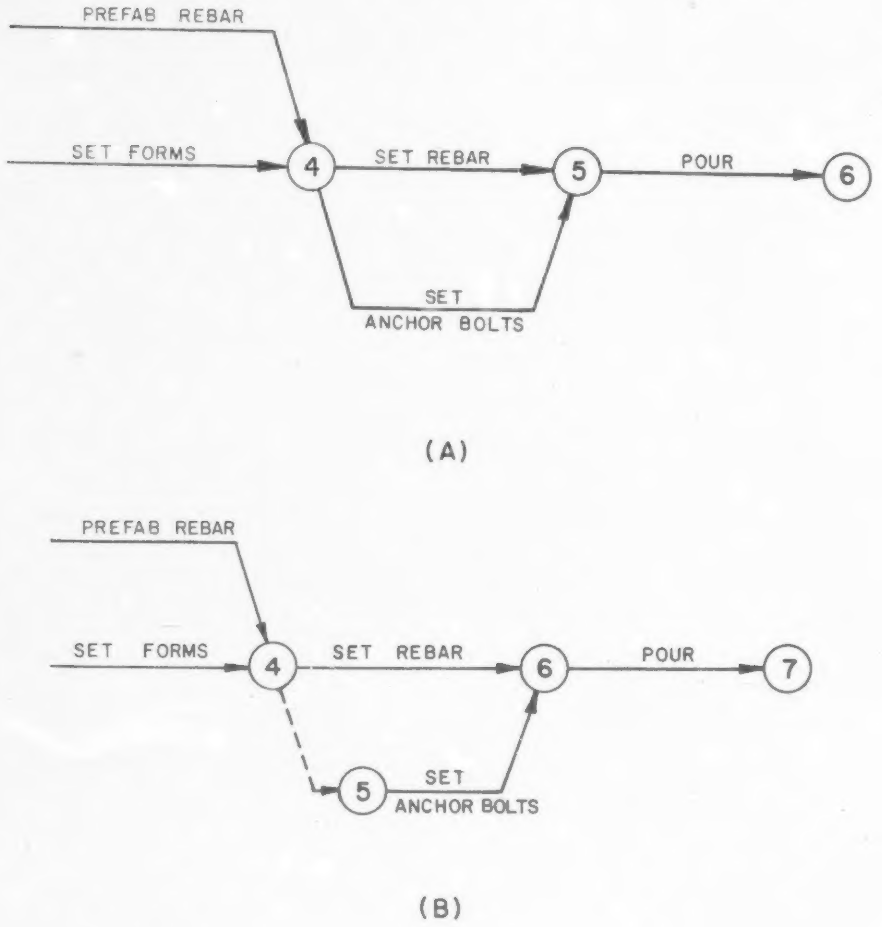
The second reason for using a dummy is somewhat more complex. A connector type activity is sometimes needed to describe dependencies in such a way that non-dependent activities are not shown as dependent. This can be illustrated also with the diagram from problem 3.

If the problem were changed by eliminating the assumption that FINE GRADE had to precede the setting of the forms, one would be tempted to produce an arrow diagram that looked like view A of figure 3-39.

This approach, however, is incorrect because it is not possible to SET FORMS unless at least the excavating has been completed. Another solution–which is also incorrect–might be to combine event number (2) and event (3). Event (3) would then appear as in view B of figure 3-39.

The error in this arrow diagram exists because FINE GRADE and ADVISE AVAILABILITY OF BACKHOE do not depend upon the completion of PREFAB FORMS as indicated, but rather only on LAY OUT AND EXCAVATE.

The correct solution is one in which SET FORMS is indicated as depending upon both PREFAB FORMS as well as on LAY OUT AND EXCAVATE, and in which FINE GRADE and ADVISE AVAILABILITY OF BACKHOE depend only on LAY OUT AND EXCAVATE. The proper way to show this situation is by



117.325X

Figure 3-38. —Using a dummy to maintain the uniqueness of the I - J identification system.

using the first solution with a DUMMY from (2) to (3), as illustrated in view C of figure 3-39.

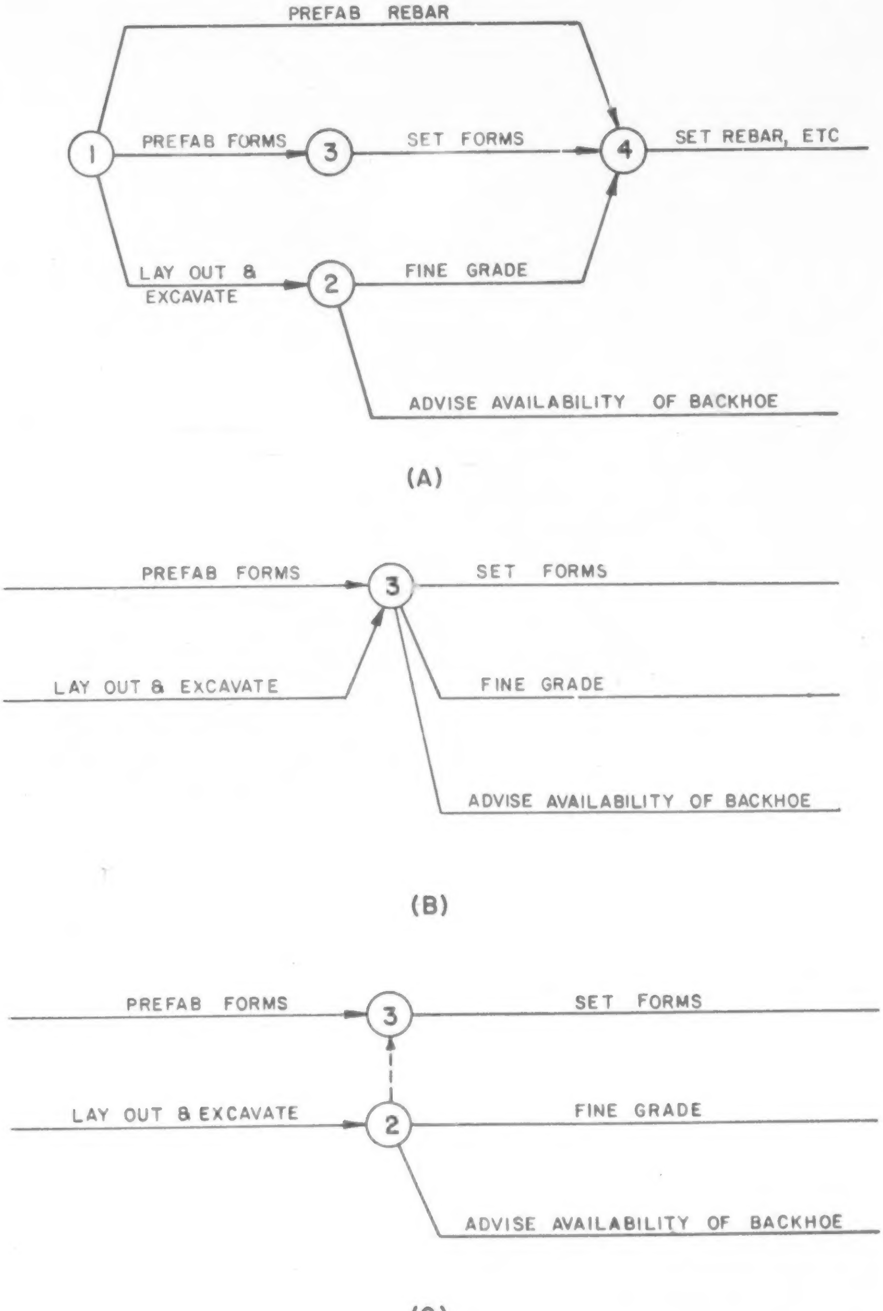
Because the DUMMY from (2) to (3) has a zero duration, it is finished when event (2) occurs. It merely transfers, then, the dependency relationship—the sequence—desired to event (3).

The second reason for using a DUMMY is to establish a dependency or sequence without confusing non-dependent activities.

DUMMY PROBLEM

Go back to the very first problem in this section. There it was assumed that only one man would work on the job. If the job is broken into segments to show how several crews would get the job done, the activity list could be almost doubled. Assume for this problem that each of those original activities will now be done each in two phases. That is, approximately half the ditch will be dug before the "gravel crew" will start placing gravel, and the gravel will be in half the ditch before the crew installing the draintile can start work. The activity list would then consist of the following items:

1. OBTAIN DRAINTILE
2. DIG DITCH FIRST HALF


PREFAB REBAR
1
PREFAB FORMS
3
SET FORMS
4
SET REBAR, ETC
LAY OUT & EXCAVATE
2
FINE GRADE
ADVISE AVAILABILITY OF BACKHOE
(A)
PREFAB FORMS
3
SET FORMS
LAY OUT & EXCAVATE
FINE GRADE
ADVISE AVAILABILITY OF BACKHOE
(B)
PREFAB FORMS
3
SET FORMS
LAY OUT & EXCAVATE
2
FINE GRADE
ADVISE AVAILABILITY OF BACKHOE
(C)

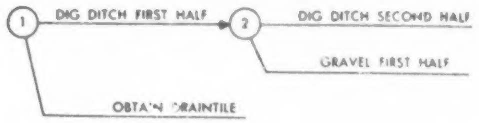
117.326X

Figure 3-39. —Using a dummy to establish a dependency or sequence without confusing non-dependent activities.

3. DIG DITCH SECOND HALF
4. PLACE GRAVEL FIRST HALF
5. PLACE GRAVEL SECOND HALF
6. INSTALL DRAINTILE FIRST HALF
7. INSTALL DRAINTILE SECOND HALF

It must be assumed for this problem that the first half of each job will be finished before the second half starts. Assumed also is that OBTAIN DRAINTILE is a delivery type of activity, and that the ditch will be backfilled as part of the INSTALL DRAINTILE operation.

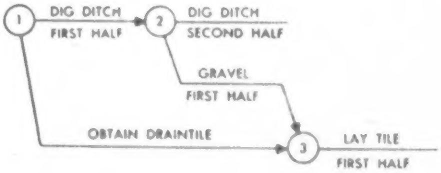
The initial activities would be drawn in as follows:


1
DIG DITCH FIRST HALF
2
DIG DITCH SECOND HALF
GRAVEL FIRST HALF
OBTAIN DRAINTILE

117.327X

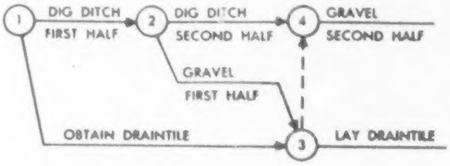
This arrangement of activities indicates that when DIG DITCH FIRST HALF is complete, two activities can start. DIG DITCH SECOND HALF and GRAVEL FIRST HALF. Independently, OBTAIN DRAINTILE can occur any time after the start of the project.

When the gravel is in the first half of the ditch, if the draintile is on hand, the draintile can be installed. The diagram would grow to look like this:


1
DIG DITCH
FIRST HALF
2
DIG DITCH
SECOND HALF
GRAVEL
FIRST HALF
OBTAIN DRAINTILE
3
LAY TILE
FIRST HALF

117.328X

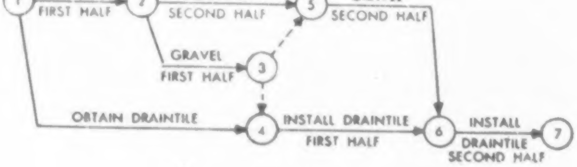
When the second half of the ditch had been dug, the gravel could be placed. However, the assumption was made that the first half of any job would have to be completed before starting the second half. This causes a problem insofar as the present version of the diagram is concerned. It is desired to show that GRAVEL SECOND HALF depends upon DIG DITCH SECOND HALF and GRAVEL FIRST HALF. Tying this new activity to the ditch digging operation is no problem but difficulties arise when GRAVEL FIRST HALF is considered. The problem is caused by the fact that GRAVEL FIRST HALF has been tied into event (3). If the end of GRAVEL FIRST HALF is connected to the beginning of GRAVEL SECOND HALF, and a dummy is about the only way this could be done, a serious sequence error is committed.


1
DIG DITCH
FIRST HALF
2
DIG DITCH
SECOND HALF
4
GRAVEL
SECOND HALF
GRAVEL
FIRST HALF
OBTAIN DRAINTILE
3
LAY DRAINTILE

117.329X

The diagram, as it appears above, indicates that GRAVEL SECOND HALF cannot start until OBTAIN DRAINTILE has been completed. That is, the diagram states that it is impossible to place gravel unless draintile is on hand. No such assumption was made, so this is incorrect.

The problem is solved by rearranging the diagram as originally created and splitting GRAVEL FIRST HALF into two paths. Dummy activities are, of course, required to do this. The final solution to this expanded drainage ditch problem appears below.


1
DIG DITCH
FIRST HALF
2
DIG DITCH
SECOND HALF
5
GRAVEL
SECOND HALF
GRAVEL
FIRST HALF
3
OBTAIN DRAINTILE
4
INSTALL DRAINTILE
FIRST HALF
6
INSTALL
DRAINTILE
SECOND HALF
7

117.330X

ADVANCED PROBLEM

It is desired to create an arrow diagram for the steps necessary to be taken in the production of a hollow metal door and frame assembly. The activities involved in this project are as follows:

1. MAKE DOOR
2. INSTALL LOCK IN DOOR
3. PUT HINGES ON DOOR
4. ASSEMBLE DOOR FRAME COMPLETELY
5. INSTALL DOORBELL ON FRAME
6. HANG DOOR
7. CLEAN UP SITE

There are several assumptions that must be considered in this project. These are:

A. The frame is complete prior to bell installations.
B. The lock is installed prior to hanging.
C. The hinges must be on the door before hanging.
D. The door frame must be assembled prior to the hanging.
E. The part of the lock that is in the frame, and the part of the hinges that is part of the frame, is taken care of when the frame is assembled
F. Clean up is the final activity.
G. There are no space or manpower limitations.

The solution to this problem is shown in view A of figure 3-40.

Note that there are two dummy activities in this diagram–one for each of the two reasons discussed earlier. Activity (3) - (5) exists so that the I - J's remain unique for INSTALL LOCK and for INSTALL HINGES. Activity (4)- (5) shows that HANG DOOR must wait until ASSEMBLE DOOR FRAME has been completed but INSTALL BELL does not depend on anything except ASSEMBLE DOOR FRAME. This problem can be made somewhat more complex by adding just three new activities. These are:

8. DELIVER BLUEPRINTS FOR FRAME AND DOOR
9. DELIVER LOCK HARDWARE
10. DELIVER HINGE HARDWARE

Note that the blueprints are for the frame and the door only. They are not needed to obtain the lock and the hinges. When the arrow diagram for this problem is drawn, the dependencies must be checked very carefully. It is very easy to mistakenly indicate that the installation of the hinges depends upon the lock delivery and/or that the installation of the lock depends upon the hinge delivery. The solution to this problem is shown in view B of figure 3-40.

DURATION ESTIMATES

The next stage of input development involves the element of time. This requires the planner to estimate the amount of time that will be necessary to complete each activity, or the duration time of each activity. This is necessary in order to produce the CPM SCHEDULE for the project. The arrow diagram describes how the activities fit together; the duration estimates indicate how long each will take.

Duration estimates can be made in a variety of ways. The simplest way is to determine the "normal" amount of time needed to finish the activity with a normal sized crew or with the normal amount of equipment. In addition to this simple approach, the CPM user has the ability to examine a range of durations for the activities so as to produce more than one schedule for the project, starting with the longest duration for each activity and then "speeding up" those that will shorten the project.

It must be emphasized that when duration estimates are made, they are made on an individual activity basis. That is, no consideration of other activities can be made. Remember that the planning phase–in which the duration estimates are made–is entirely separate from the scheduling phase.

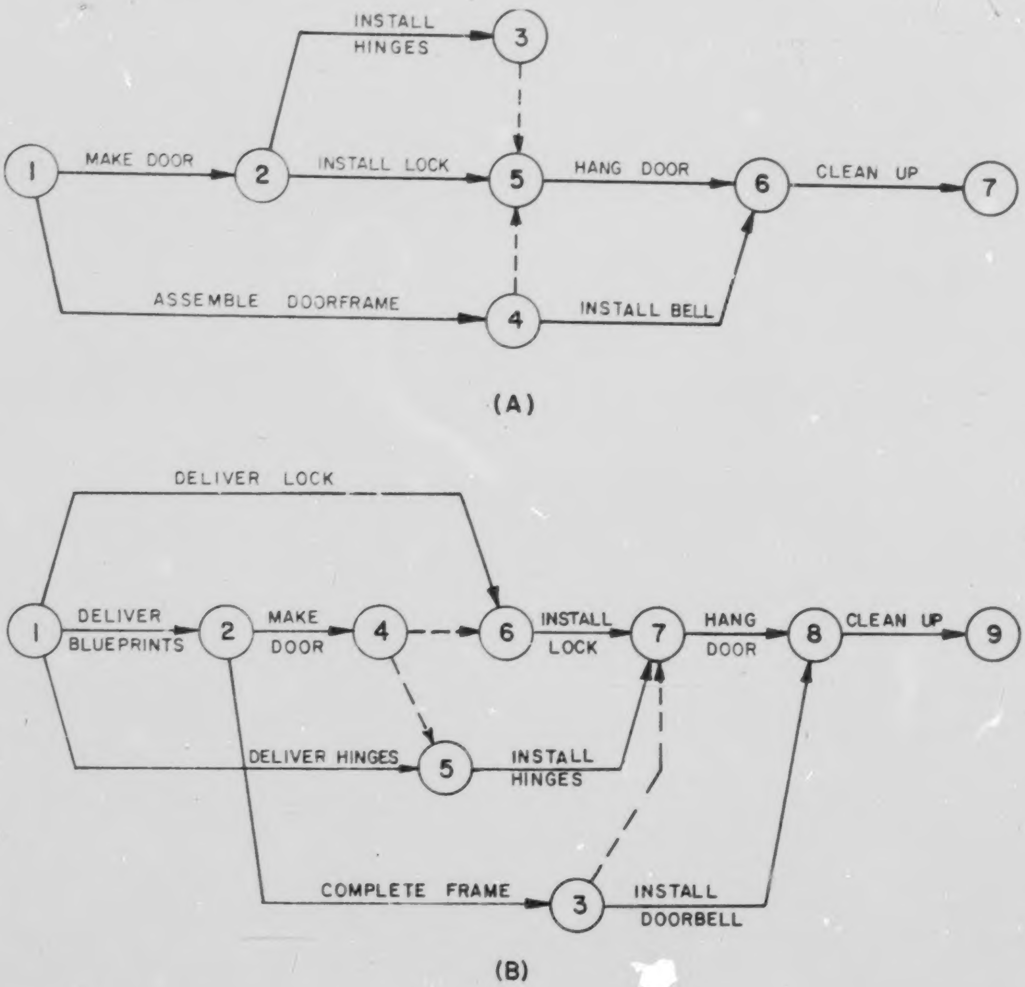

INSTALL HINGES
3
1
MAKE DOOR
2
INSTALL LOCK
5
HANG DOOR
6
CLEAN UP
7
ASSEMBLE DOORFRAME
4
INSTALL BELL
(A)
DELIVER LOCK
1
DELIVER BLUEPRINTS
2
MAKE DOOR
4
6
INSTALL LOCK
7
HANG DOOR
8
CLEAN UP
9
DELIVER HINGES
5
INSTALL HINGES
COMPLETE FRAME
3
INSTALL DOORBELL
(B)

Figure 3-40. —Advanced problem diagram development.

117.331X

The duration estimate is used to calculate the schedule for a project. It is also used to find those activities that are controlling the amount of time needed to get the project done. These are the critical activities and collectively they make up "The Critical Path".

The critical path is the longest path—in time—through the network. Since these critical activities are added to determine the total duration of the project, any delay of one of these activities will proportionately delay the job—and conversely, any speed-up will decrease the total duration time.

Look at the example illustrated in figure 3-41. In this arrow diagram, durations have been assigned each of the activities. The diagram indicates that activity A—a twelve-day item—must be finished before the four-day activity B [(2) - (4)] can begin, and that B must be finished before activity C [(4) - (7)] can start, etc.

This diagram contains three paths. A first path consists of activities A, B, and C. The amount of time required to complete this set of activities is the total of activities A, B, and C, or 24 days.

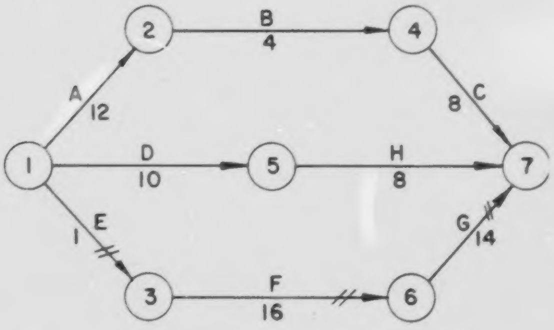


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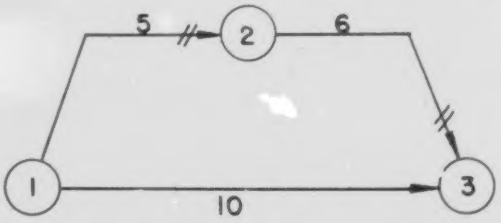
Figure 3-41. —Determining the critical path.



117.333X

Figure 3-42. —Simplified example.

A second path through this network is made up of activities E, F, and G. This path requires a total of 31 days to finish, (1 + 16 + 14).

A third path in the network is also possible. It is made up of activities D and H. The duration of this path is 10 + 8, or 18 days.

The longest path in time through the network illustrated is thus E, F and G. This then is the critical path and is indicated by small double slants on the arrows. If it is desired or required that the amount of time needed to complete the project be shortened, these are the activities upon which to concentrate. Non-critical activities are strictly dependent upon the completion of the critical items, so speeding up non-critical activities is of no value at all, in terms of project duration.

It turns out generally that a very small number of activities make up the critical path—usually less than thirty per cent of the total activities. This means that a large percentage of the activities in a project have extra time available—since they are, in a sense, waiting for the critical items to be completed. A project manager can adjust his non-critical activities to take best advantage of weather conditions, manpower and equipment availabilities, and other items, without delaying the project.

An important point to keep in mind when using CPM is that there is not necessarily only one critical path. There may be several. Also, remember that if a critical path is shortened, a new "parallel" path will most likely become critical. In the simplified example illustrated in figure 3-42, the critical path goes through the top activities. If these are shortened by only one day, however, the bottom path becomes a parallel critical path. Any further reducing of the amount of time required to get the project finished would have to be done on both critical paths.

When project managers and other upper echelon people study over the network or arrow diagram they want to pick out important or significant conditions or events quickly. To enable them to do this, you may be asked to identify the key events as "milestones." MILESTONES may be indicated by the use of a slightly different symbol, or they may be shown as regular events with a special notation on the diagram as to its significance, such as "interior wiring completed" or "roof completed".

The Planning Phase is the most important of the three phases in CPM. The steps taken in this phase determine whether or not CPM will be used successfully. Because of this, extreme care must be taken to make certain that a complete and careful job is done in the production and collection of the necessary input information.

CPM SCHEDULING

When a project has been planned on an arrow diagram, the next step is to schedule it—that is, to place it on a working timetable. When this has been done, it will be possible to determine when each of the various activities must be performed, when deliveries must take place, how much (if any) spare time there is for each activity, and when completion of the whole operation may be expected. It will also be possible to determine which activities are critical, and to what extent a delay in one activity will affect succeeding activities.

EARLIEST EVENT TIMES

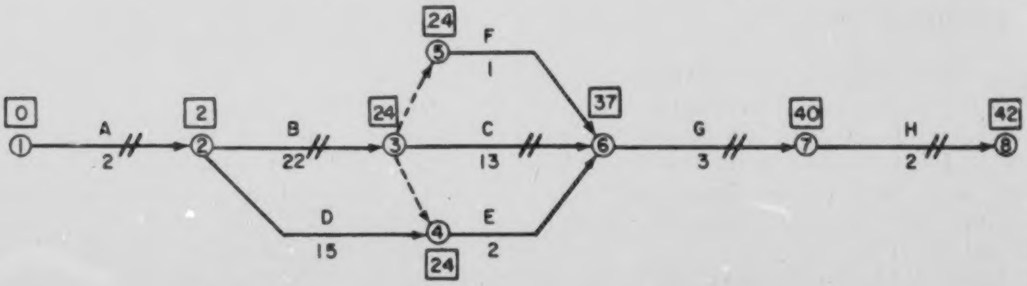
The earliest time at which an event can occur is the sum of the durations of the activities on the LONGEST PATH leading up to the event. This time is entered in a box next to the event on the arrow diagram, as shown in figure 3-43.

The times shown are, of course, project times–that is, successive WORKING days, not successive calendar days, reckoned from 0 at the tail of the first arrow. The duration of the first activity in figure 3-43 is 2 days; therefore, event (2) occurs at project time 2. The time for event (3) is the sum of the duration times of activities (1)-(2) and (2)-(3), or 24. However, there are two paths leading to event (4): one from event (1) through (2) for a total of 17, the other from event (1) through (2) and (3) for a total of 24. Following the rule of selecting the longest path, the earliest event time for event (4) is 24. Similarly, three paths lead to event (6), and the longest from event (1) through (2) and (3) is selected, giving an earliest event time for event (6) of 37.

LATEST EVENT TIMES

You also need to know the latest time at which an event can occur. To determine this, you begin at the end of the project and work backward. To calculate the latest time at which an event can occur, subtract the duration of the immediately following job from the immediately following latest event time. The latest event time is entered in a small triangle adjacent to the box containing the earliest event time, as shown in figure 3-44.

In that figure, the latest event times for events (6), (7), and (8) are the same as the earliest event times. This follows from application of the rule given. The latest event time for event (7), for example, equals the latest event time for



82.106

Figure 3-43. —Earliest event times on arrow diagram.

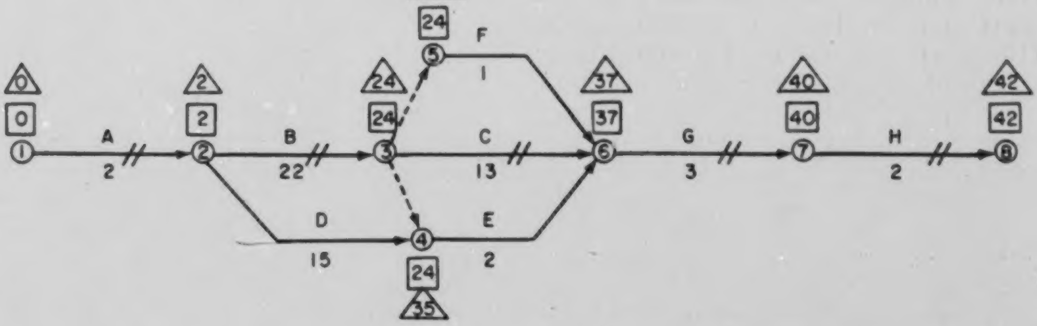


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Figure 3-44. —Latest event times on arrow diagram.

event (8), which is 42, minus the duration of activity (7)-(8), which is 2. The remainder is 40.

However, the latest event time for event (4) equals the latest time for event (6), which is 37, minus the duration of activity (4)-(6), which is 2, or 35. The latest event time for event (5) equals the latest event time for event (6), which is 37, minus the duration of activity (5)-(6), which is 1, or 36. The latest event time for event (3) equals the latest event time for event (6), which is 37, minus the duration of activity (3)-(6), which is 13, or 24.

Note that for an activity on the critical path the earliest event time and the latest event time are the same; it is only for activities not on the critical path that these event times differ. It follows that identical earliest and latest event times are another means of identifying activities on the critical path.

EARLIEST AND LATEST JOB START AND FINISH TIMES

Figure 3-45 shows a fully developed arrow diagram for the project of building an arch-type magazine, with all activities included, with earliest and latest event times inscribed. With earliest and latest event times established, earliest and latest starts and finishes for activities can be determined.

In figure 3-45, for example, what are the latest and the earliest days on which waterproofing of the topside of the arch can be started? What are the earliest and latest days on which the installation of the ventilator can be started?

Before either of these jobs can begin, the stripping of the arch forms, which is activity (9)-(10), must be completed. This activity is on the critical path, and it will be completed at project time 24. The waterproofing of the arch and the installation of the ventilator must be completed by project time 37, if the project is not to be delayed.

The waterproofing is a 2-day job. It can begin as early as day 25 (day of completion of stripping of arch forms plus 1), or as late as day 36 (final deadline for completion minus 2 plus 1). It can be completed as early as day 26 or as late as day 37. Similarly, the installation of the ventilator can begin as early as day 25 or as late as day 37, and can end as early as day 25 or as late as day 37.

The rules for calculating start and finish days for an activity, then, are as follows:

Earliest start day: earliest event time at the tail of the arrow plus 1.

Earliest finish day: earliest start time plus job duration.

Latest start day: latest event time at the head of the arrow minus job duration plus 1.

Latest finish day: latest event time at the head of the arrow.

To calculate earliest finish days, you work from left to right on the diagram, adding job durations to earliest event times. To calculate latest start times, you work from right to left, subtracting job duration from preceding latest event time.

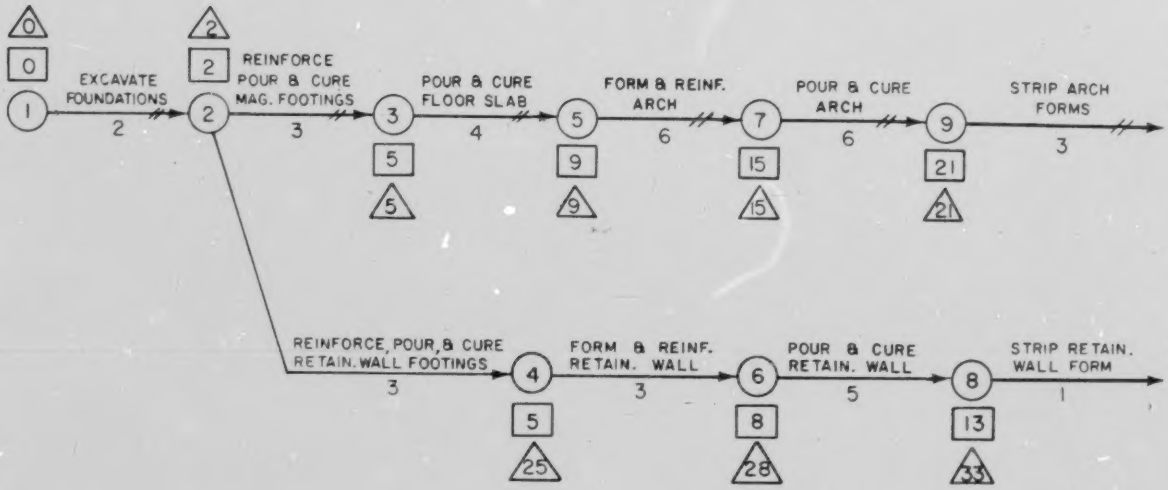
Results are entered in a schedule as shown in figure 3-46. This schedule assumes that all jobs will be started as early as possible.

CONCEPT OF FLOAT

The spare time available to perform a task such as the installation of the ventilator in figure 3-45 is called FLOAT. Properly controlled, the manipulation of float is valuable in determining the most efficient use of manpower, equipment, and materials. The existence of float allows latitude in the timing of the jobs with which it is associated. On the other hand, a job having no float is inflexible; it must start and end precisely at specific times, or the completion of the project will be affected.

Rule for Calculating Float

In figure 3-45, the installation of the ventilator has 12 days of float, because it is a 1-day job and there are 13 days available in which it may be performed. Similarly, the waterproofing job in the same figure has 11 days of float. To calculate float, subtract both the duration and the earliest event time at the tail of the arrow from the latest event time at the head of the arrow. For activity (6) - (8), for example, the float comes to 33 - 8 - 5, or 20.

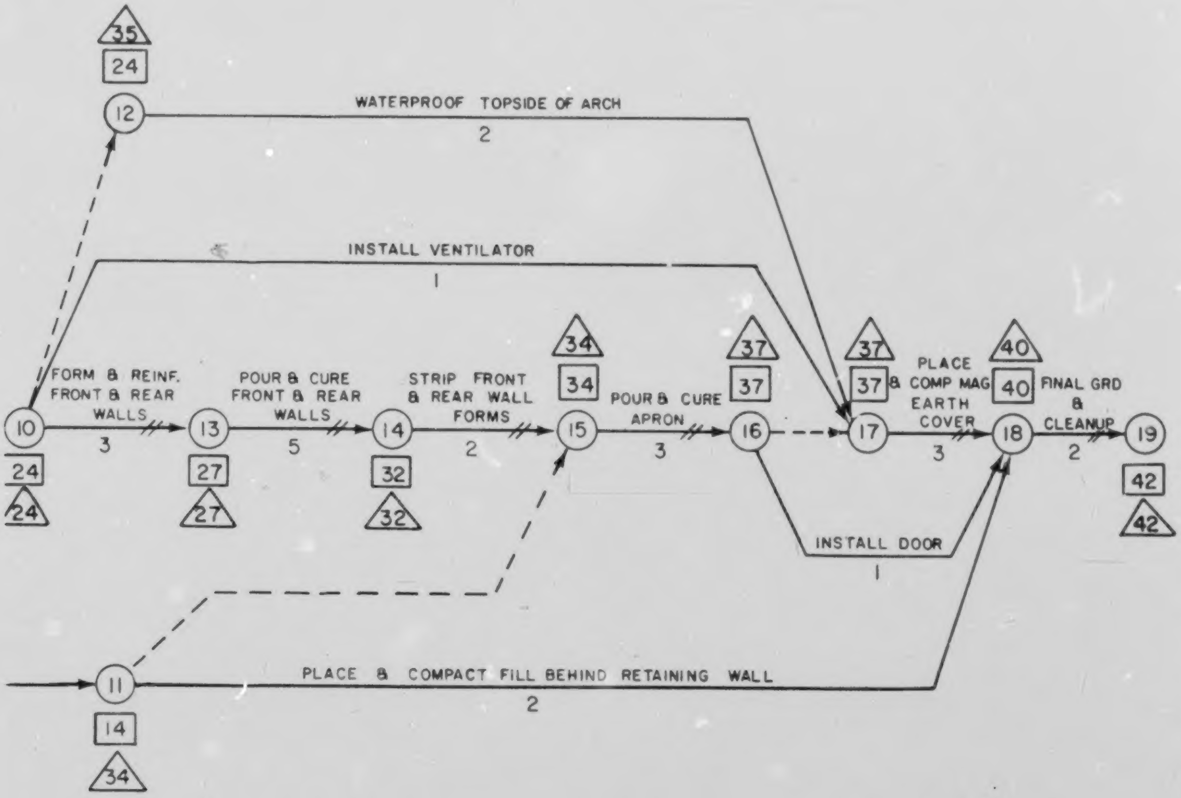

0
0
1
EXCAVATE FOUNDATIONS
2
2
2
2
REINFORCE POUR & CURE MAG. FOOTINGS
3
3
5
5
POUR & CURE FLOOR SLAB
4
5
9
9
FORM & REINF. ARCH
6
7
15
15
POUR & CURE ARCH
6
9
21
21
STRIP ARCH FORMS
3
REINFORCE, POUR, & CURE RETAIN. WALL FOOTINGS
3
4
5
25
FORM & REINF. RETAIN. WALL
3
6
8
28
POUR & CURE RETAIN. WALL
5
8
13
33
STRIP RETAIN. WALL FORM
1

Each of the noncritical activities along the path from event (2) to event (11) has 20 days of float when considered independently. However, there are only 20 days of float available for the whole chain, calculated as follows: 34 - 2 - (3 + 3 + 5 + 1) = 34 - 2 - 12 = 20. Fundamentally, the reason is the fact that when float is calculated independently for each separate activity, it is assumed that all the preceding activities were started as early as possible. However, as soon as any float is used, the float available to subsequent activities is correspondingly reduced.

Suppose, for example, that activity (4) - (6) was delayed for 3 days. The succeeding activity (6) - (8) would have 3 days added to its earliest event time and subtracted from its float. The float for activity (6) - (8) would then be 33 - 11 - 5, or 17.

Use of Float in Allocation of Manpower and Equipment

In the construction of the high-explosives magazine diagrammed in figure 3-45, there are three jobs of form stripping to be done. The stripping of the arch is critical, and must be performed between project times 21 and 24. Similarly, the stripping of the front and rear wall forms must be done between day 32 and day 34. However, the stripping of the retaining wall forms is a 1-day job which may be done at any time between project time 13 and project time 34. Obviously, the crew should be scheduled to strip the retaining wall at a time when they are not busy with the arch or front and rear wall forms. Similarly, the pouring and curing should be scheduled so as to take advantage of the float in activity (6) - (8). By starting activity (6) - (8)


35
24
12
WATERPROOF TOPSIDE OF ARCH
2
INSTALL VENTILATOR
1
FORM & REINF. FRONT & REAR WALLS
3
10
24
24
13
27
27
POUR & CURE FRONT & REAR WALLS
5
14
32
32
STRIP FRONT & REAR WALL FORMS
2
34
34
15
POUR & CURE APRON
3
37
37
16
37
37
17
PLACE & COMP MAG EARTH COVER
3
40
40
18
FINAL GRD & CLEANUP
2
19
42
42
INSTALL DOOR
1
11
14
34
PLACE & COMPACT FILL BEHIND RETAINING WALL
2

82.108.1

Figure 3-45. —Diagram for high-explosives magazine.

one day after its earliest start time, it can be performed concurrently with activity (5) - (7). Thus, by using up a day of float, more efficient use is made of crew and equipment.

Adjustment of Float

Earliest and latest event times shown in the arrow diagram (fig. 3-45) were changed to reflect the days dropped out as a result of weekend curing. A check was then made to ensure that the critical path was still the same, since shortening the original critical path might cause another to take its place. Next, the float was recalculated, and the new float values were entered in the timetable (fig. 3-47). Notice that on the timetable activity (11) - (18) and activity (17) - (18), both of which consist of placing and compacting fill (see fig. 3-45), are scheduled about a month apart. Since activity (11) - (18) shows 20 days of float, however, and since the same equipment will be used for both activities, the float for activity (11) - (18) will probably be used to schedule this activity to end the day before activity (17) - (18) begins.

PREPARING A TIMETABLE

After the arrow diagram has been completed and the float has been calculated, a timetable like the one shown in figure 3-47 can be prepared. This is a timetable derived from the arrow diagram shown in figure 3-45. Obviously, project day 1 falls on 1 March, a Thursday. No

ACTIVITY (I, J)	PROJECT DAY				REMARKS
	START		FINISH		
	EARLIEST	LATEST	EARLIEST	LATEST	
(1, 2)	1	1	2	2	critical
(2, 3)	3	3	5	5	critical
(2, 4)	3	23	5	25	
(3, 5)	6	6	9	9	critical
(4, 6)	6	26	8	28	
(5, 7)	10	10	15	15	critical
(6, 8)	9	29	13	33	
(7, 9)	16	16	21	21	critical
(8, 11)	14	34	14	34	
(9, 10)	22	22	24	24	critical
(10, 12)	0	0	0	0	dummy
(10, 13)	25	25	27	27	critical
(10, 17)	25	37	25	37	
(11, 15)	0	0	0	0	dummy
(11, 18)	15	39	16	40	
(12, 17)	25	36	26	37	
(13, 14)	28	28	32	32	critical
(14, 15)	33	33	34	34	critical
(15, 16)	35	35	37	37	critical
(16, 17)	0	0	0	0	dummy
(16, 18)	38	40	38	40	
(17, 18)	38	38	40	40	critical
(18, 19)	41	41	42	42	critical

82.109

Figure 3-46. —Project schedule for CPM arrow diagram shown in figure 3-45.

work is done on Saturdays or Sundays; therefore, though project days 1 and 2 fall on Thursday and Friday, 1 and 2 March, project day 3 falls on Monday, 5 March. As you can see, however, Saturdays and Sundays are included in the calendar when they can be utilized as curing time for concrete jobs. When this is done, such a Saturday or Sunday becomes a project day, and if the day relates to a job on the critical path, the effect is to gain time by cutting a day from the schedule. In figure 3-47, 5 days were cut from the critical path by scheduling concrete work so that curing could occur on weekends.

For example: activity (3) - (5) consisted of placing and curing the magazine footings. It was started on Thursday, so that curing could be scheduled for Saturday and Sunday. Since this job was on the critical path, the use of Saturday and Sunday for curing cut 2 days from the schedule.

The schedule that stays completely accurate through the entire life of a project, as originally developed, is extremely rare. Periodic revision and refinement is a necessary and valuable part of CPM. It is up to the CPM user to analyze his schedule to make certain that it is meaningful

ACTIVITY (I, J)	PROJECT DAYS		CALENDAR DAYS		FLOAT
	START	DURATION	START	FINISH	
(1, 2)	1	2	March 1, Thurs.	March 2, Fri.	0
(2, 3)	3	3	March 5, Mon.	March 7, Wed.	0
(2, 4)	3	3	March 5, Mon.	March 7, Wed.	16[2]
(3, 5)[1]	6	4	March 8, Thurs.	March 11, Sun.	0
(4, 6)	6	3	March 8, Thurs.	March 12, Mon.	16[2]
(5, 7)	10	6	March 12, Mon.	March 19, Mon.	0
(6, 8)	9	5	March 13, Tues.	March 17, Sat.	16[2]
(7, 9)	16	6	March 20, Tues.	March 25, Sun.	0
(8, 11)	14	1	March 19, Mon.	March 19, Mon.	16[2]
(9, 10)	22	3	March 26, Mon.	March 28, Wed.	0
(10, 12)	–	0	–	–	0
(10, 13)	25	3	March 29, Thurs.	April 2, Mon.	0
(10, 17)	25	1	March 29, Thurs.	March 29, Thurs.	11[2]
(11, 15)	–	0	–	–	0
(11, 18)	15	2	March 20, Tues.	March 21, Wed.	20[2]
(12, 17)	25	2	March 29, Thurs.	March 30, Fri.	10[2]
(13, 14)[1]	28	5	April 3, Tues.	April 7, Sat.	0
(14, 15)	33	2	April 9, Mon.	April 10, Tues.	0
(15, 16)	35	3	April 11, Wed.	April 13, Fri.	0
(16, 17)	—	0	———	———	0
(16, 18)	38	1	April 16, Mon.	April 16, Mon.	2
(17, 18)	38	3	April 16, Mon.	April 18, Wed.	0
(18, 19)	41	2	April 19, Thurs.	April 20, Fri.	0

[1] Curing scheduled for weekend.
[2] Adjusted to reflect weekend curing.

82.110

Figure 3-47. —Timetable from arrow diagram shown in figure 3-45.

and accurate, and to enforce the accomplishment of it.

Since many services, trades, and supplies are required during the course of construction, senior representatives from the ratings or departments responsible for the various activities should be consulted during the planning and scheduling phases of CPM. CPM requires a team effort on the part of all responsible parties involved in the project to make it work effectively.

CHAPTER 4

CONCRETE CONSTRUCTION

Concrete construction, once confined largely to paving and foundations, has been developed to the point where both large and small buildings are now constructed entirely of concrete with concrete joists (usually called floor beams), concrete studs (usually called columns), concrete walls, concrete floors, and concrete roofs.

In this chapter, we discuss some of the major factors concerning the design of concrete forms and, by means of specific examples, show you some of the procedures used in form design. Information is also provided on the various methods by which you can select the proportions for quality concrete mixtures and adjust these mixtures to suit job requirements. We also discuss the types and uses of admixtures, slump testing procedures, and the preparation of concrete test specimens. We point out some of the types of equipment you are likely to encounter in concrete construction and in the preparation of concrete block, both of which play a vital role nowadays in SEABEE construction. A brief discussion is also included on precast concrete.

There may be other jobs considered more dangerous than concrete construction, but we believe concrete still deserves its share of safety measures, so we provide some information on concrete safety along with a few hints on supervision.

FORMWORK

Formwork is a temporary structure that supports its own weight and that of the freshly placed concrete as well as the live loads imposed upon it by materials, equipment, and workmen. As a Builder serving in the capacity of a form designer or as the supervisor of a form building crew, you should take into account the three principal objectives of formwork which are safety, quality, and economy.

Economy is a major concern since formwork may represent as much as one-third of the total cost of a concrete structure. Savings depend on the ingenuity and experience of the formwork designer or supervisor. Judgment in the selection of materials and equipment, in planning fabrication and erection procedures, and in scheduling reuse of forms, will expedite the job and help reduce formwork costs. In designing and building formwork you should aim for maximum economy without sacrificing quality or safety. Short-cuts in design or construction that endanger quality or safety may be false economy. If forms do not produce the specified surface finish, for example, much hand rubbing of the concrete may be required; or if forms deflect excessively, bulges in the concrete may require expensive chipping and grinding. Obviously economy measures that lead to formwork failure also defeat their own purpose. The most commonly used form materials are earth, metal, lumber, and plywood.

Earth forms are used in subsurface construction where the soil is stable enough to retain the desired shape of the concrete structure. The advantages of this type of form are less excavation required and better settling resistance. The obvious disadvantage is a rough surface finish, so the use of earth forms is generally restricted to footings and foundations.

Metal forms are used where added strength and weight ratio are the same or where the construction will be duplicated at another location. Metal forms are more expensive, but they may be more economical than wooden forms if they can be used often enough. Examples of their use would be highway paving forms, curb and sidewalk forms, and metal pans for overhead slab forms.

Practically all formwork jobs require some lumber. Any lumber that is straight and structurally strong and sound may be used for formwork, although the abundance of softwoods makes them generally most economical for all types of formwork. The softwoods are usually lighter in weight and are easier to work with, though not all species are truly softer than the so-called hardwoods. Added economy may result from reusing form lumber later for roofing, bracing, or similar purposes. Partially seasoned stock is used for formwork, since fully dried lumber has a tendency to swell when soaked with water from the concrete, and green lumber tends to dry out and warp during hot weather, causing difficulties of alignment and uneven surface. Lumber that comes in contact with the concrete should be surfaced on one side at least and on both edges. The surfaced side is turned toward the concrete. The edges of the lumber may be square, shiplap, or tongue and groove. The latter makes a more watertight joint and tends to prevent warping.

Plywood is the most commonly used sheathing material in concrete form construction. Softwood plywood, which is used for concrete forms, is manufactured from several species of woods, of which Douglas fir is the most common. The 1/2, 5/8, and 3/4 in. thicknesses of plywood in 4 x 8 ft sheets are most commonly used for formwork, with 1/4-in. plywood frequently used to line forms and to form curved surfaces. A wide range of thicknesses is obtainable when needed, but the thicknesses from 1/4 to 1 in. are more widely available. In addition to the standard 4 x 8 ft sheets, 5 ft widths, and lengths ranging from 5 to 12 ft are often available. Softwood plywood is made in two types, exterior (bonded with waterproof glue) and interior (bonded with water-resistant glue). Both types are used for formwork, but the exterior type is preferred where maximum reuse is desired. Within each type, panels are made up of several grades of veneer ranging from A to D, depending on their surface characteristics. Grade B-B, commonly used for formwork, has both faces of B-grade veneer, which is a smoothly sanded solid-surface with circular repair plugs and tight knots of up to one inch permitted Grade B-B plywood carried in the Federal supply system is labeled as special concrete form grade, meaning that it is edge sealed and mill oiled. Mill oiling does not eliminate the need for oiling or coating on the job, but mill oiled plywood gives better service than that which is job treated only. Edge sealing protects the glue line from moisture, thereby increasing its reusability.

FORM DESIGN

Forms must be designed for all the weight they are liable to be subjected to including the dead load of the forms, plastic concrete in the forms, the weight of workmen, weight of equipment and materials whose weight may be transferred to the forms, and the impact due to vibration. These factors vary with each project, but none should be neglected. Ease of erection and removal are also important factors in the economical design of forms. Platforms and ramp structures independent of formwork are sometimes preferred to avoid displacement of forms due to loading and impact shock from workmen and equipment. Formwork for concrete must support all vertical and lateral loads that may be applied until such time as these loads can be carried by the concrete structure itself. Loads on the forms include the weight of reinforcing steel and fresh concrete, the weight of the forms themselves, and various live loads imposed during the construction process. Consideration must be given to such conditions as unsymmetrical placement of concrete, uplift, and concentrated loads produced by storing supplies on the freshly placed slab. Rarely will there be precise information as to the loads the formwork may be subjected to; therefore, the designer must make some safe assumptions which will hold good for conditions generally encountered.

Vertical Loads

Vertical loads on formwork include the weight of reinforced concrete together with the weight of forms themselves which are regarded as dead loads, and the live loads imposed by the workmen and the equipment during construction. The majority of all formwork involves concrete weighing 150 pounds per cubic foot. Minor variations in this weight are not significant, and in most cases 150 lb per cu ft, including weight of reinforcing steel, is commonly assumed for design. Formwork weights vary from as little as 3 o. 4 psf to 10 to 15 psf. When the formwork weight is small in relation to the weight of concrete plus live load, it is frequently neglected. If concrete weighs 150 lb per cu ft, it will place a load on the forms of 12.5 lb per sq ft for each inch of slab thickness. Thus a 6 inch slab would produce a dead load of 6 x 12.5 or 75 psf, excluding the weight of forms. The recommended minimum construction live load to provide for the weight of workmen and equipment is 50 psf of horizontal projection. If powered concrete buggies are used in concreting operations, it is recommended that 75 psf be used as a minimum construction live load.

Lateral Pressure

When concrete is placed in the form it is in a plastic state and behaves temporarily like a fluid, producing a hydrostatic pressure that acts laterally on the vertical forms. If concrete acted as a true liquid, the pressure developed would be equal to the density of fluid (150 lb per cu ft is commonly assumed for concrete) times the depth in feet to the point at which the pressure was being considered. However, plastic concrete is a mixture of solids and water whose behavior only approximates that of a liquid, and then for a limited time only. This lateral pressure is comparable to full liquid head when concrete is placed full height within the period required for its initial set. With slower rates of placing, concrete at the bottom of the forms begins to harden and the lateral pressure is reduced to less than full fluid pressure by the time concreting is completed in the upper parts of the form.

The effective lateral pressure, a modified hydrostatic pressure, has been found to be influenced primarily by the rate of placing and temperature of the concrete mix. Other variables which have been found to have an effect on lateral pressure include: consistency of concrete, amount and location of reinforcement, vibration, maximum aggregate size, and placing procedures. However, with usual concreting practices, the range of these variables' effects is generally small and is usually neglected or compensated for in design tables.

Lateral Loads

Adequate lateral bracing is extremely important to stability and safety in formwork construction, but all too often it is treated carelessly or even omitted entirely. Formwork must be braced to resist all foreseeable lateral loads, such as those imposed by wind and dumping of concrete or other impact such as starting and stopping of equipment. There are many types of braces which can be used to give forms stability. The most common type is a diagonal member and horizontal member nailed to a stud or wale. The diagonal member should make a 45° angle with the horizontal member. Additional bracing may be added to the form by placing vertical members (strongbacks) behind the wales or by placing vertical members in the corner formed by intersecting wales.

WALL FORM DESIGN

It is desirable to design forms according to a step-by-step procedure to assure the consideration of all pertinent factors. The sequence of these steps depends in large measure on the materials available to do the job. No attempt is made here to explain all the procedures involved in the analysis of form materials, but rather to acquaint you with the procedures commonly used by Builders to design wall forms. Wooden forms for a concrete wall should be designed by the following steps:

1. Determine the materials availabie for sheathing, studs, wales, braces, shoe plates and tie wires.
2. Determine the mixer output by dividing the mixer yield by the batch time. Batch time includes loading all ingredients, mixing, and

unloading. If more than one mixer will be used, multiply output by the number of mixers.

$$\text{MIXER OUTPUT (cu ft/hr)} = \frac{\text{Mixer yield (cu ft)}}{\text{Batch time (min)}} \quad \frac{60\ \text{min}}{\text{hr}}$$

3. Determine the area that is enclosed by the forms.

Plan area (sq ft) = L x W

4. Determine the rate (vertical feet per hour) of placing the concrete in the form by dividing the mixer output by the plan area.

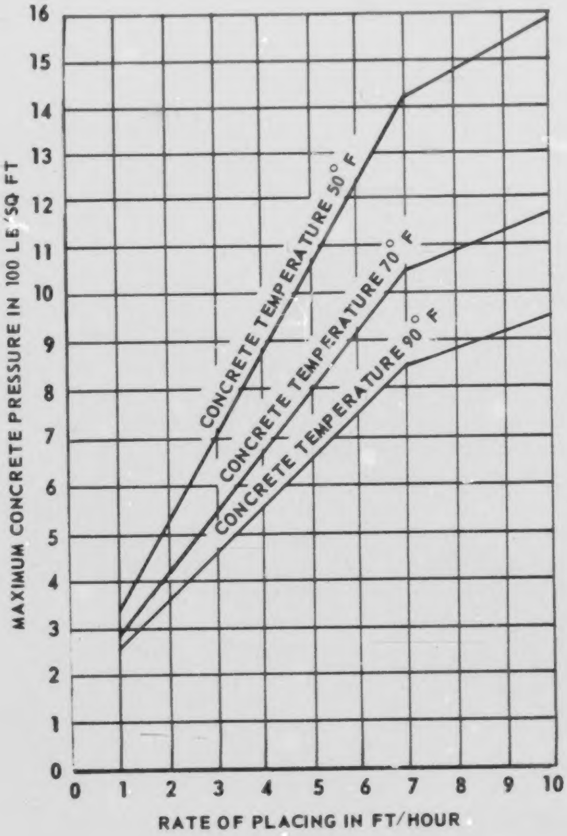
$$\text{Rate of placing (ft/hr)} = \frac{\text{Mixer output (cu ft/hr)}}{\text{Plan area (sq ft)}}$$

5. Make a reasonable estimate of the placing temperature of the concrete.

6. Determine the maximum concrete pressure (lateral pressure) by entering the bottom of figure 4-1 with the rate of placing. Draw a line vertically up until it intersects the correct concrete temperature curve. Read horizontally across from the point of intersection to the left side of the graph and determine the maximum concrete pressure.

7. Determine the maximum stud spacing by entering the bottom of figure 4-2 with the maximum concrete pressure. Draw a line vertically up until it intersects the correct sheathing curve. Read horizontally across from the point of intersection to the left side of the graph. If the stud spacing is not an even number of inches, round the value of the stud spacing down to the next lower even number of inches. For example, a stud spacing of 17.5 inches would be rounded down to 16 inches.

8. Determine uniform load on a stud by multiplying the maximum concrete pressure by the stud spacing.

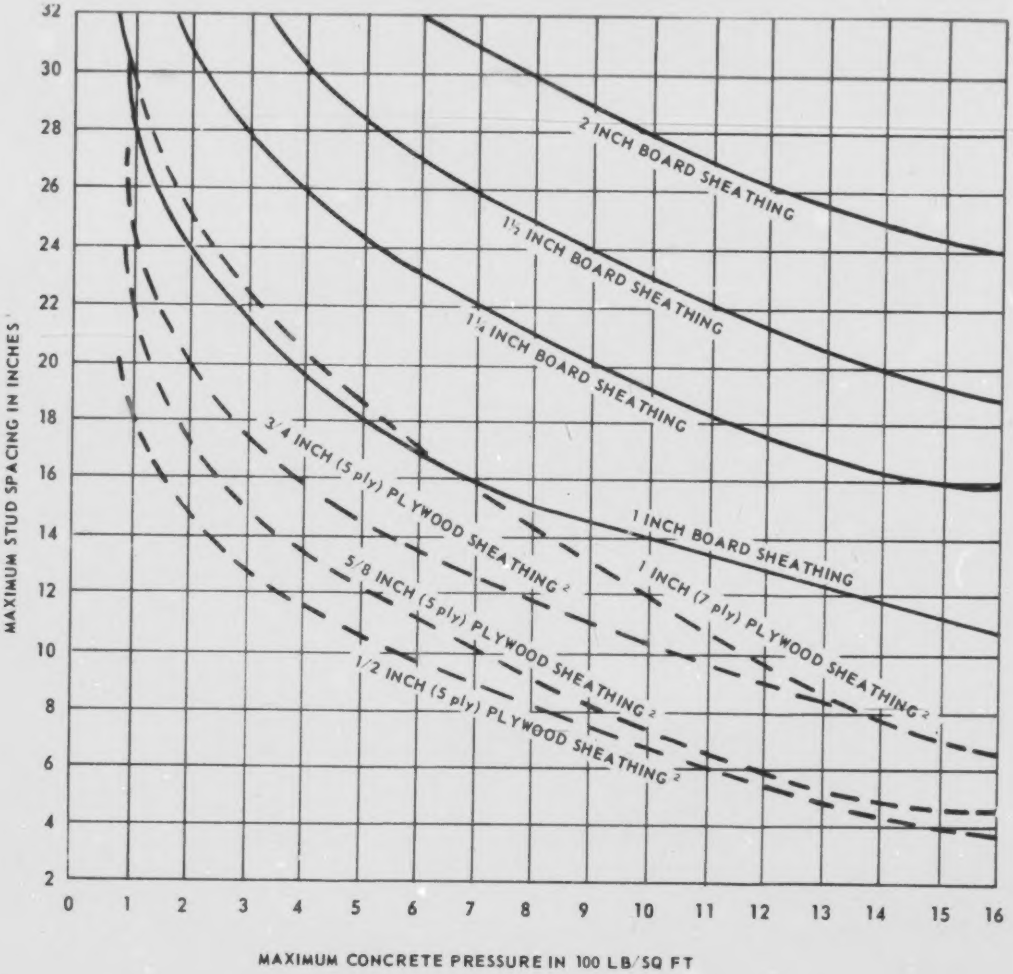


45.467

Figure 4-1. –Maximum concrete pressure graph.

Uniform load on stud (lb/lineal ft) =
Maximum concrete pressure
(lb/sq ft) x stud spacing (ft)

9. Determine the maximum wale spacing by entering the bottom of figure 4-3 with the uniform load on a stud. Draw a line vertically up until it intersects the correct stud size curve. Read horizontally across from the point of intersection to the left side of the graph. If the wale spacing is not an even number of inches, round the value of the wale spacing down to the next lower even number of inches. The wale spacing thus determined applies to double wales of which each member is the same size as the studs.



[1] MAXIMUM ALLOWABLE STUD SPACING = 32 INCHES

[2] SANDED FACE GRAIN PARALLEL TO SPAN

45.468

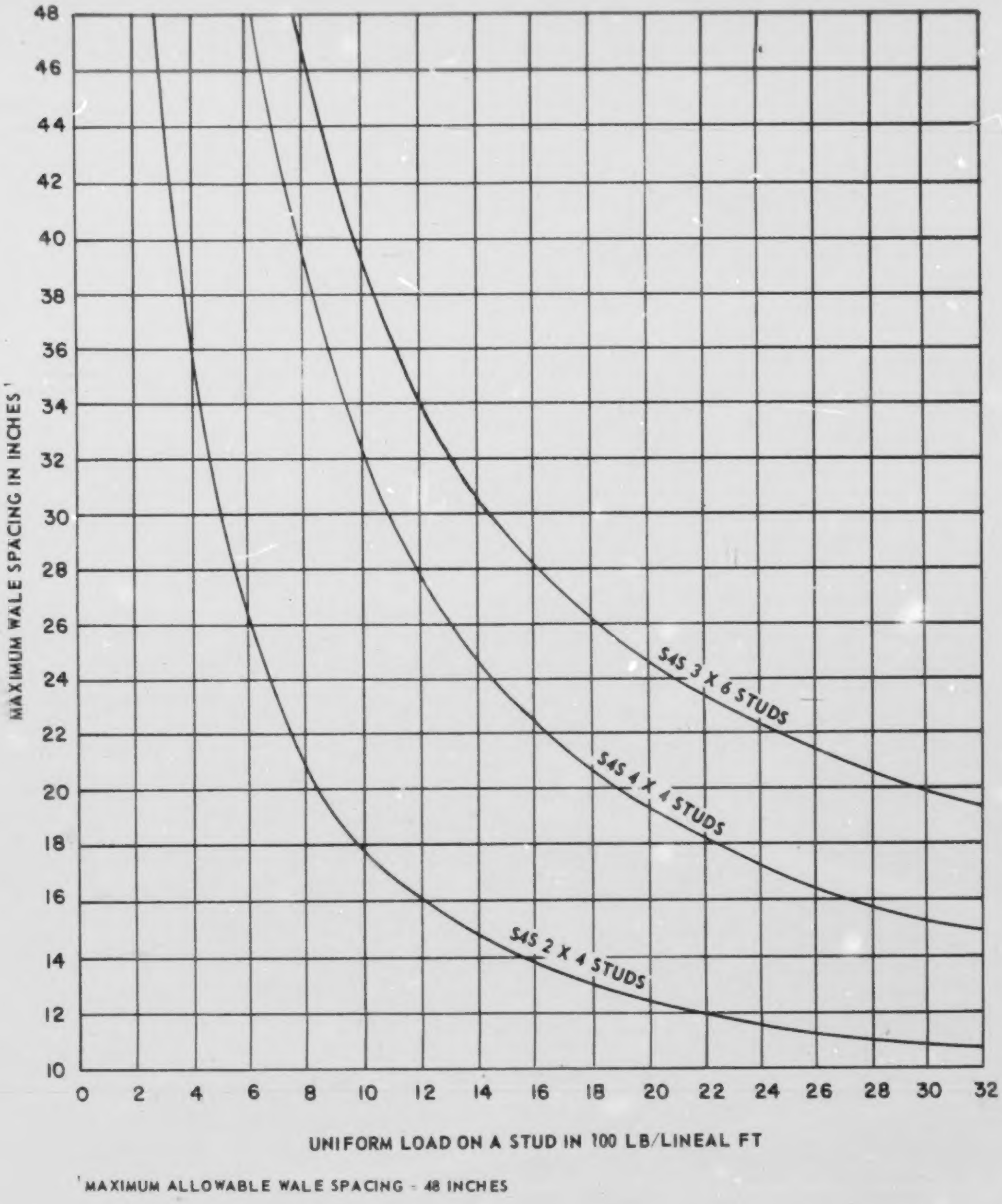
Figure 4-2. —Maximum stud spacing graph.

10. Determine the uniform load on a wale by multiplying the maximum concrete pressure by the wale spacing.

Uniform load on wale (lb/lineal ft) =
Maximum concrete pressure
(lb/sq ft) x wale spacing (ft)

11. Determine the tie wire spacing, based on the wale size, by entering the bottom of figure 4-4 with the uniform load on a wale. Draw a line vertically up until it intersects the correct double wale size curve. Read horizontally across from the point of intersection to the left side of the graph. If the tie spacing is not an even number of inches, round the value of the tie spacing down to the next lower even number of inches.

12. Determine the tie wire spacing based on the tie wire strength by dividing the tie wire strength by the uniform load on a wale. If the



45.469

Figure 4-3. —Maximum wale spacing graph.

tie wire spacing is not an even number of inches, round the computed value of the tie spacing down to the next lower even number of inches. If possible, use a tie wire size that will provide a tie spacing equal to or greater than the stud spacing. Always use a double strand of wire. If the strength of the available tie wire is unknown, the minimum breaking load for a double strand

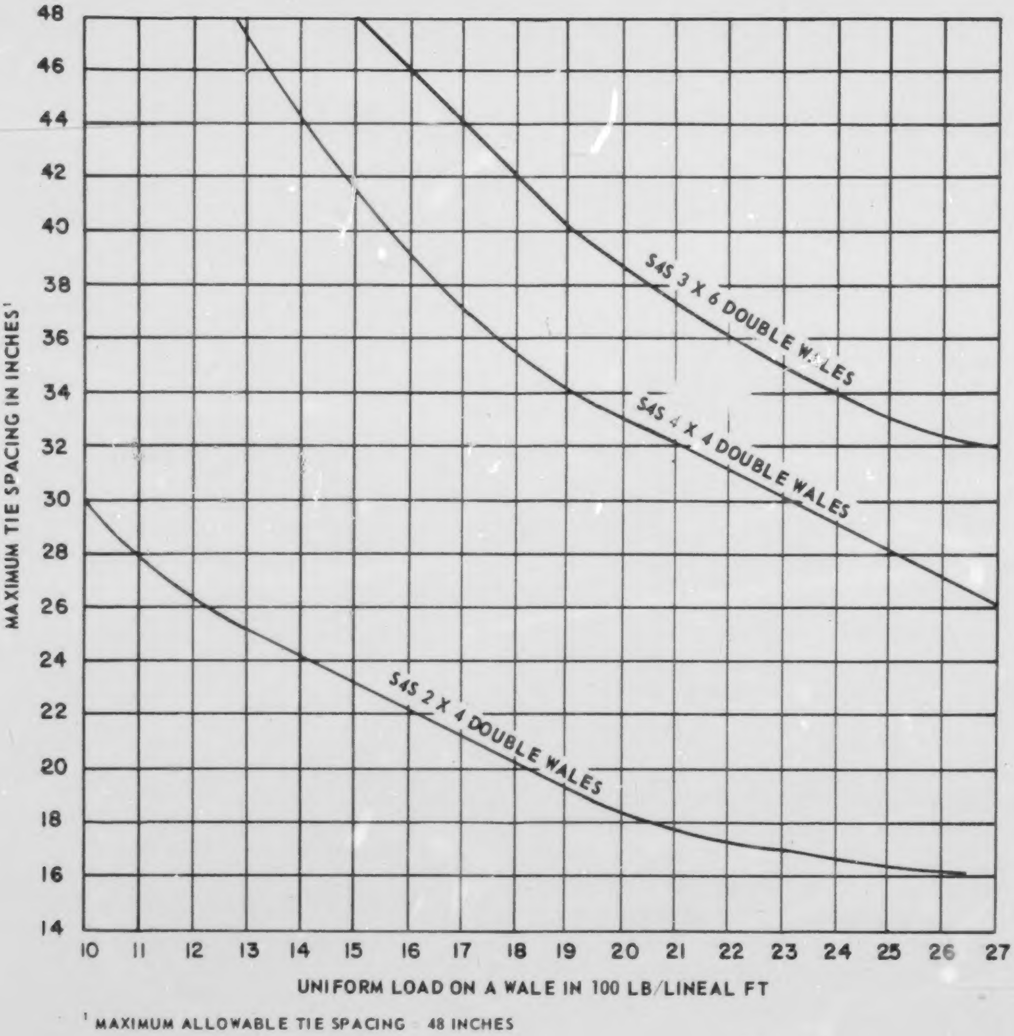


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Figure 4-4. —Maximum tie wire spacing.

of wire (found in the Navy supply system) is given in table 4-1.

$$\text{Tie wire spacing (in.)} = \frac{\text{Tie wire strength (lbs) x 12 in/ft}}{\text{Uniform load on wale (lb/ft)}}$$

13. Determine the maximum tie spacing by selecting the smaller of the tie spacings based on the wale size and on the tie wire strength.

14. Compare the maximum tie spacing with the maximum stud spacing. If the maximum tie spacing is less than the maximum stud spacing, reduce maximum stud spacing to equal the maximum tie spacing and tie at the intersections of the studs and wales. If the maximum tie spacing is greater than the maximum stud spacing, tie at the intersections of the studs and wales.

NOTE: SNAP TIES, TIE RODS, or other such manufactured devices are often used in

Table 4-1.–Breaking Load of Wire

STEEL WIRE

Size of wire Gage No.	Minimum breaking load double strand Pounds
8	1700
9	1420
10	1170
11	930

BARBED WIRE

Size of each wire Gage No.	Minimum breaking load Pounds
$12\frac{1}{2}$	950
13[1]	660
$13\frac{1}{2}$	950
14	650
$15\frac{1}{2}$	850

[1] Single strand barbed wire

117.338

place of tie wires when available. If used, spacing requirements can be determined using the procedures outlined in steps 11 through 14 above.

15. Determine the number of studs for one side of a form by dividing the form length by the stud spacing. Add one (1) to this number and round up to the next integer. During form construction, place studs at the spacing determined above. The spacing between the last two studs may be less than the maximum allowable spacing.

$$\text{No. of studs} = \frac{\text{Length of form (ft)} \times 12 \text{ (in/ft)}}{\text{Stud spacing (in.)}} + 1$$

16. Determine the number of wales for one side of the form by dividing the form height by the wale spacing and round up to the next integer. Place the first wale one-half space up from the bottom and the remainder at the maximum wale spacing.

17. Determine the time required to place the concrete by dividing the height of the form by the rate of placing.

Sample Wall Form Design Problem

Design the forms for a concrete wall 32 ft long, 2 ft thick, and 8 ft high. A 16S mixer is available and the crew can produce a 16 cu ft batch of concrete every 5 minutes. The concrete temperature is estimated to be 70°F. Material available for use in constructing forms includes 2 x 4's and 3/4-inch plywood sheathing.

SOLUTION STEPS:

1. Material available: 2 x 4's, 3/4-inch plywood sheathing and number 9 wire.

2. Mixer output =

$$\frac{16 \text{ cu ft}}{5} \times \frac{60}{\text{hr}} =$$

$$16 \times 12 = 192 \text{ cu ft/hr}$$

3. Plan area of forms =

$$32 \text{ ft} \times 2 \text{ ft} = 64 \text{ sq ft}$$

4. Rate of Placing =

$$\frac{192}{64} = 3 \text{ ft/hr}$$

5. Temperature of concrete: 70°F

6. Maximum concrete pressure (fig. 4-1) =

540 psf

7. Maximum stud spacing (fig. 4-2) =

14 inches

8. Uniform load on studs =

$$540 \times \frac{14}{12} = 630 \text{ lb/lineal ft}$$

9. Maximum wale spacing (fig. 4-3) =

24+, use 24 inches

10. Uniform load on wales =

$$540 \times \frac{24}{12} = 1080 \text{ lb/lineal ft}$$

11. Tie wire spacing based on wale size (fig. 4-4) = 24+ inches

12. Tie wire spacing based on wire strength =

$$\frac{1420 \times 12}{1074} = 14+, \text{ use 14 inches}$$

13. Maximum tie spacing = 14 inches

14. Maximum tie spacing equals maximum stud spacing; therefore, tie at the intersection of each stud and double wale.

15. Number of studs per side =

$$\left(32 \times \frac{12}{14} \right) + 1 =$$

27.4 + 1, use 29 studs

16. Number of double wales per side =

$$8 \times \frac{12}{24} = 4$$

17. Time required to place concrete =

$$\frac{8}{3} = 2 \text{ hr and 40 min}$$

Bracing Requirements

In the absence of controlling specifications or precise information on lateral loadings that will occur, it is recommended that wall forms be braced for a minimum lateral load of 100 lb per lineal ft of wall applied at the top of the forms. Bracing can be accomplished by the use of guy wires or wooden struts.

GUY WIRE BRACING.–If guy wires are used to brace the wall forms just designed they must be placed on both sides of the forms as they act only in tension. Tension in the wire depends on the angle it makes with the wall; this tension can be calculated easily using the relationship between sides of a right triangle. For example, if stakes to which guys are attached are set 6 ft away from the base of the 8 ft wall: The length of the wire in tension would equal the square root of $8^2 + 6^2$ or 10 ft. To determine the tension in the wire, divide the lateral load by the height of the wall and multiply by the length of the wire. Thus:

$$\text{Tension in wire} = \frac{100}{8} \times 10 \text{ or } 125 \text{ lbs}$$

This indicates a 125-lb tension load for every ft of wall braced; therefore, if guys were placed at 8 ft intervals along the wall, the total tension in each wire would be 8 x 125 or 1,000 lb. With the working strength of guy material known, guys can be spaced to use their maximum safe load capacity. Stakes must be securely placed to resist this load, and top wales must be able to carry the additional horizontal forces accumulated at each point where the guys are attached.

WOODEN STRUT BRACING.–If wooden strut bracing is provided for this same wall, then single side bracing may be used. If the bracing were attached 2 or 3 ft below the top of the wall, the bracing must carry more than the 100 lb per lineal ft load applied at the top of the forms. The horizontal resisting force 2 ft below the top of the forms would have to be 8/6(100) or approximately 134 lb per ft in order to balance the 100 lb per ft design load applied at the top of the wall. If this were the case and the end of the diagonal brace (strut) is placed 6 ft from the wall, the length of the strut and the load it must carry can be determined using the relationship between sides of a right triangle.

The length of the strut would be equal to the square root of $6^2 + 6^2$ or approximately 8.48 ft. To determine the compression (or tension) in the strut, divide the lateral load by the height of the form at the intersection of the strut and multiply by the length of the strut. Thus:

$$\text{Compression in strut} = \frac{134}{6} \times 8.48 \text{ or}$$

approximately 190 lb per ft

This indicates a 190-lb compression (or tension) load for every ft of wall braced. Entering figure 4-5 at the unsupported strut length of 9 ft, you find that the safe axial load

SAFE AXIAL LOADS – DRESSED (S4S) SIZES
CONSTRUCTION GRADE DOUGLAS FIR OR NO. 1 SOUTHERN PINE

NOMINAL LUMBER SIZE, INCHES	2 X 4	2 X 6	4 X 4
UNSUPPORTED LENGTH, FT			
4	3,560	5,550	15,800
5	2,280	3,550	15,800
6	1,580	2,460	15,800
7	1,160	1,810	12,900
8	890	1,380	9,890
9	700	1,090	7,820
10	570	690	6,330
11		7[illegible]0	5,230
12			4,400

117.339

Figure 4-5. —Allowable loads on simple shores and wooden strut bracing.

for a 2 x 4 is 700 lb. By dividing the load per ft of wall braced (190 lb) into the safe axial load (700 lb) you can determine the strut spacing. In this example, the spacing would be approximately 3.7 ft. If this spacing is inconvenient, you could use larger lumber (if available) or double the spacing and use bracing members on both sides of the forms. Whichever method is selected, care should be taken to ensure that all connections are made strong enough to withstand the compression and/or tension loads.

COLUMN FORM DESIGN

As with wall forms, column forms are designed according to a step-by-step procedure to assure the consideration of all pertinent factors. Wooden forms for a concrete column should be designed by the following steps:

1. Determine the materials available for sheathing, yokes, and battens. Standard materials for column forms are 2 x 4's and 1-inch sheathing.
2. Determine the height of the column.
3. Determine the largest cross-sectional dimension of the column.
4. Determine the yoke spacing by entering table 4-2 and reading down the first column until the correct height of column is reached. Then read horizontally across the page to the column headed by the largest cross-sectional dimension. The center-to-center spacing of the second yoke above the base yoke will be equal to the value in the lower interval that is partly contained in the column height line. All subsequent yoke spacings may be obtained by reading up this column to the top. This procedure gives maximum yoke spacings. Yokes may be placed closer together if desired. Table 4-2 is based upon use of 2 x 4's and 1-inch sheathing.

Sample Column Form Design Problem

Design the forms for a concrete column 2 ft by 3 ft, 9 ft high. 2 x 4's and 1-inch sheathing are available.

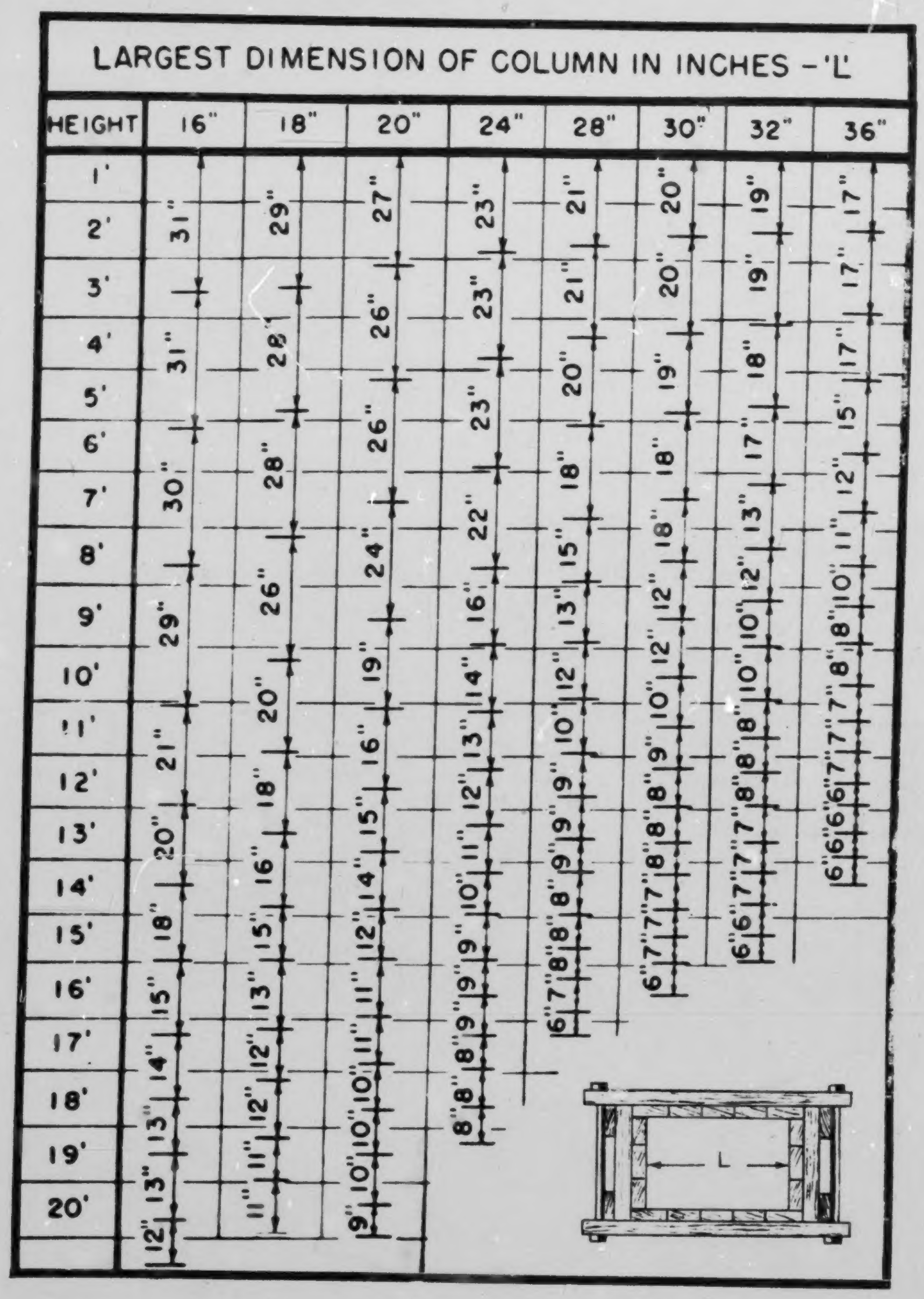
SOLUTION STEPS:

1. Material available: 2 x 4 yokes and 1-inch sheathing.
2. Height of column is 9 ft.
3. Largest cross-sectional dimension of the column is 36 inches.
4. Maximum yoke spacing for column (table 4-2) starting from the bottom of form are 8", 8", 10", 11", 12", 15", 17", 17", and 10". The space between the top two yokes has been reduced because of the limits of the column height.

Bracing Requirements

Because of their height and relatively small cross-sectional area, column forms require four-way bracing to ensure alignment and resistance to wind loading and various other lateral forces that may occur during concreting operations. As with wall forms, guy wire or wooden strut bracing may be designed to offset the specified or anticipated lateral forces on column forms.

Table 4-2.–Column Yoke Spacing


HEIGHT
1'
2'
3'
4'
5'
6'
7'
8'
9'
10'
11'
12'
13'
14'
15'
16'
17'
18'
19'
20'
L

LARGEST DIMENSION OF COLUMN IN INCHES – 'L'							
16"	18"	20"	24"	28"	30"	32"	36"
31"	29"	27"	23"	21"	20"	19"	17"
31"	28"	26"	23"	21"	20"	19"	17"
30"	28"	26"	23"	20"	19"	18"	17"
29"	26"	24"	22"	18"	18"	17"	15"
21"	20"	19"	16"	15"	18"	13"	12"
20"	18"	16"	14"	13"	12"	12"	11"
18"	16"	15"	13"	12"	12"	10"	10"
15"	15"	14"	12"	10"	10"	10"	8"
14"	13"	12"	11"	9"	9"	8"	8"
13"	12"	11"	10"	9"	8"	8"	7"
13"	12"	11"	9"	8"	8"	7"	7"
12"	11"	10"	9"	8"	7"	7"	7"
	11"	10"	9"	8"	7"	7"	6"
		10"	8"	7"	7"	6"	6"
		9"	8"	6"	6"	6"	6"
			8"				6"

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OVERHEAD SLAB FORM DESIGN

The general goal of slab form design is a balanced form design, one that loads all the parts at or near their safe carrying capacity. Often the preliminary design has to be adjusted to fit the module used in structural design, or it may be modified to improve the balance and use of materials more efficiently. Here again it is desirable to follow step-by-step procedures to assure the consideration of all pertinent factors. Wooden forms for an overhead concrete slab should be designed by the following steps:

1. Determine the material available for sheathing, joists, stringers, and shores.
2. Determine the design load, a combined dead and live load for which the forms must be designed.
3. Determine the maximum allowable sheathing span (joist spacing) by entering figure 4-6 with the design load. Then read horizontally across the page to the number in the column headed by the type of sheathing being used. The number found represents the maximum allowable sheathing span; this span is the maximum allowable spacing of the joists.
4. Determine the uniform load on each joist using the following formula:

$$\text{Uniform load on joist, lb per lineal ft} = \frac{\text{joist spacing, in.}}{12} \times \text{design load, psf}$$

5. Determine the maximum allowable joist span (stringer spacing) by entering figure 4-7 with the uniform load on a joist. Then read horizontally across the page to the number in the column headed by the nominal size of the joists being used. The number found represents the maximum allowable joist span; this span is the maximum allowable spacing of the stringers.
6. Determine the uniform load on each stringer using the following formula:

$$\text{Uniform load on stringer, lb per lineal ft} = \frac{\text{stringer spacing, in.}}{12} \times \text{design load, psf}$$

DESIGN LOAD	3/4"–5 PLY PLYWOOD FACE GRAIN PARALLEL TO SPAN*	1"–7 PLY PLYWOOD FACE GRAIN PARALLEL TO SPAN*	1" BOARD**	1½" BOARD**	2" BOARD**
75	27	32	32	46	54
100	25	30	29	43	50
125	23	29	28	41	48
150	22	27	26	39	46
175	21	26	25	38	44
200	20	25	24	36	42
300	17	23	22	33	38
400	16	21	20	30	35
500	15	19	18	28	33
600	14	18	17	27	32

* B–B form grade Douglas fir

** Construction grade Douglas fir (S4S)

117.341

Figure 4-6. —Safe spacing in inches of supports for single use sheathing continuous over four or more supports.

UNIFORM LOAD	2 X 4*	2 X 6*	2 X 8*	2 X 10*
200	62	93		
300	52	79	107	
400	42	65	88	112
500	35	54	73	93
600	31	47	64	81

* Construction grade Douglas fir (S4S)

117.342

Figure 4-7. —Safe spacing in inches of supports for joists or other beam components of formwork continuous over four or more supports.

7. Determine the maximum allowable stringer span (shore spacing) by entering figure 4-7 with the uniform load on a stringer. Then read horizontally across the page to the number in the column headed by the nominal size of the stringers being used. The number found represents the maximum allowable stringer span; this span is the maximum allowable spacing of shores.

8. Determine the form area to be carried by each shore using the following formula:

Form area supported, sq ft =

$$\frac{\text{stringer spacing, in.}}{12} \times \frac{\text{shore spacing, in.}}{12}$$

9. Determine the total load to be carried by each shore using the following formula:

Total load per shore =

form area supported, sq ft x design load, psf

10. Determine if the shore material available will support the total load by referring to figure 4-5.

Sample Overhead Slab Form Design Problem

Design forms to support a 15 ft by 15 ft flat overhead slab floor 8 inches thick of conventional density concrete. Ceiling height is 8 ft. Material available for use in constructing forms includes 2 x 4's, 2 x 6's, 4 x 4's, and 1-inch board sheathing.

SOLUTION STEPS:

1. Material available: 1-inch board sheathing, 2 x 4 inch joists, 2 x 6 inch stringers, and 4 x 4 inch shores.

2. Design load:

Dead load of concrete and steel 8/12 x 150 = 100 psf

Minimum recommended live load on forms = 50 psf

Design load (weight of forms neglected) = 150 psf

3. Maximum allowable sheathing span (figure 4-6) is 26 inches. This span is the maximum allowable joist spacing. Choice of an actual spacing might depend on slab size, and the desire to divide slab dimensions into a number of equal or nearly equal formwork spans. The slab being 15 ft by 15 ft, 26 inches is a convenient spacing; 7 x 26 = 182, compared with 180 inches (15 ft). One end span could be made shorter by 2 inches. This would give 7 supporting joists for the slab at 26 inches on center and one at 24 inches.

4. Uniform load on joist =

$$\frac{26}{12} \times 150 \text{ or } 325 \text{ lb per lineal ft}$$

5. Maximum allowable joist span (figure 4-7) is approximately 49 inches by interpolation. This span is the maximum allowable stringer spacing. Looking again at the 15 ft by 15 ft slab, you can decrease this spacing by trial and error to some measurement which will give equal or nearly equal formwork spans. In this case, 45 inch spacing of stringers would give 4 equal spans for a total of 5 stringers (4 x 45 in. = 180 in. divided by 12 = 15 ft).

6. Uniform load on stringer =

$$\frac{45}{12} \times 150 \text{ or}$$

approximately 562 lb per lineal ft

7. Maximum allowable stringer span (figure 4-7) is approximately 50 inches by interpolation. This span is the maximum allowable shore spacing. Again considering the 15 ft by 15 ft slab in terms of equal formwork spans, a 45 inch span should be selected.

8. Form area supported =

$$\frac{45}{12} \times \frac{45}{12} \text{ or } 14.06 \text{ sq ft}$$

9. Total load per shore =

14.06 sq ft x 150 psf or 2,109 lb

10. Shore material available is more than adequate for this load (figure 4-5).

Another consideration of critical importance to the stability of shoring is the provision of adequate mudsills or other foundation support. A good foundation or sill distributes the shoring load over a suitable ground area. The footing must be firm, solid, or properly planked so that the superimposed load is evenly distributed to each shore. Unequal settlement of mudsills changes shore reactions and may cause dangerous overloading of some shores which do not settle as much as others. Mudsills should not be placed on recently placed backfill, frozen ground, or where water will flow over them.

Bracing Requirements

Lateral supporting braces are often necessary to increase the load carrying capacity of shore members. This is not the case with the preceding design problem. However, some bracing is desirable for all shoring systems and certain minimum lateral loads have been established for use in overhead slab form design. For slabs up to 8 inches thick and 40 ft square, the recommended minimum lateral load is 100 pounds per square foot. It must be emphasized that this is only a minimum requirement for slab form bracing. When unusual unbalanced loading from unsymmetrical placement of concrete is anticipated, or when impact from starting and stopping of unusually heavy equipment or dumping of concrete can be anticipated, a complete analysis of bracing requirements should be made.

Particular care must be taken in slab form construction to transfer lateral loads to the ground or to completed construction (such as walls or columns) of adequate strength. This may be done with guy wires, diagonal bracing, struts, or a combination of these, depending on height and location within the structure. Like wall form bracing, bracing members for overhead slabs should be selected and spaced so as to make full use of their working strength.

BEAM FORM DESIGN

Beam forms, like slab forms, carry a vertical load, and they are also subjected to the lateral pressure of freshly placed concrete just as wall forms are. Beams can be formed independently to span walls and columns or monolithically as part of a floor slab system. When formed as part of a slab system, a part of the load from the slab forms may be carried by the beam form to the supporting shores and must be accounted for in the formwork design.

Figure 4-8 shows a typical interior beam form with slab forming supported on the beam sides. This drawing indicates that 3/4-inch plywood serves as beam sides and that the beam bottom is a solid piece of 2-inch dimension lumber supported on the bottom by 4 x 4 inch T-head shores. The vertical side members, referred to in figure 4-8 as blocking, are placed between the ledger and kicker to assist in transmitting slab loads via beam action of the ledger to the supporting shores. In situations where slab loads are not excessive, and the beam is less than 20 inches deep, these members are often omitted. If this is the case, care must be taken to ensure that the nailed connections of the ledger are strong enough to transmit slab loads to the beam sides and that the beam sides are strong enough to transmit these loads to the supporting shores. However, to ensure that slab loads are safely

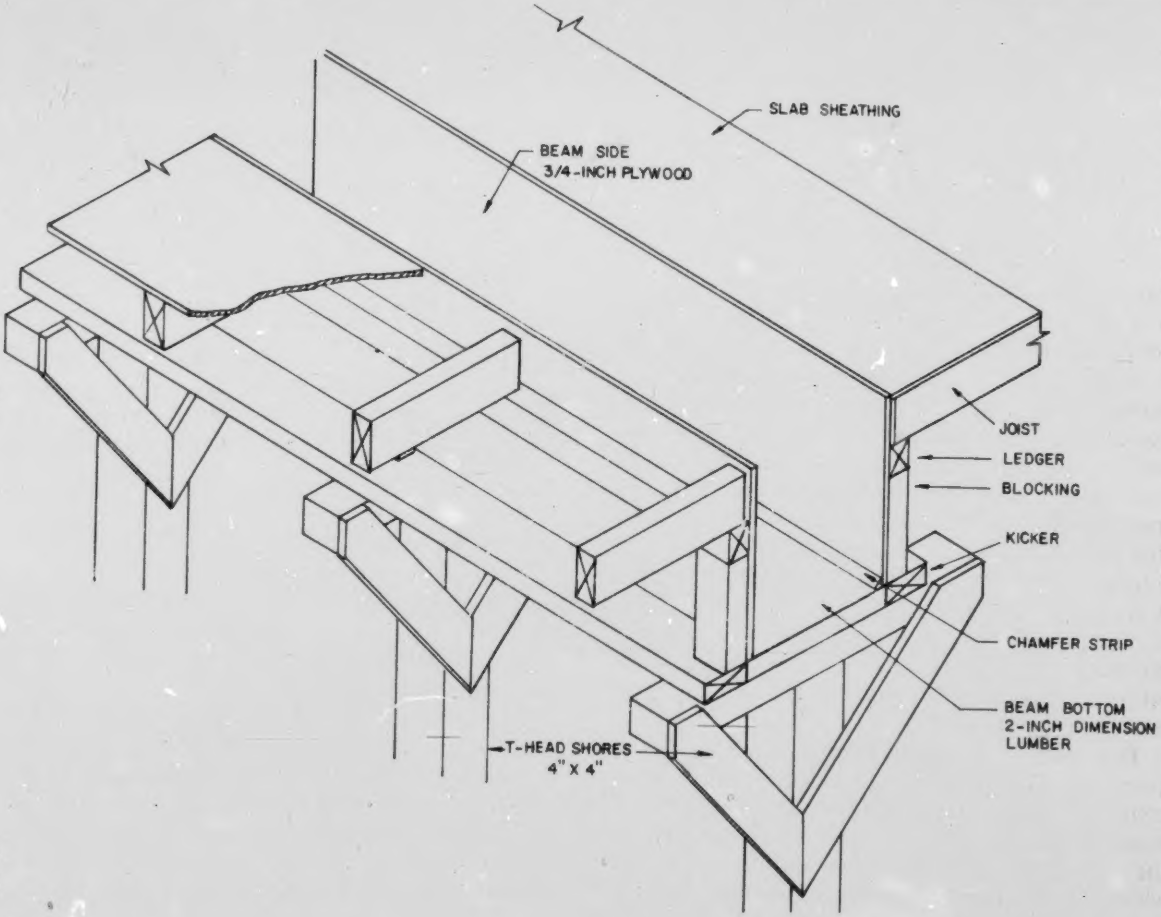


Figure 4-8. —Typical components of beam formwork with slab framing in.

117.343

transmitted to the supporting shores it is recommended that blocking be placed between the ledger and kicker at each shore. Unless extremely unusual loads are anticipated, 3/4-inch plywood is used for beam sides, and 2 x 4's are used for the ledgers, kickers, and blocking.

Close examination of figure 4-8 shows that when a beam is to be formed as part of a slab system, some of the design procedures have been completed. For example, the lateral pressure against the beam sides is compensated for by the slab joists which butt against the beam sides and rest on the attached ledger. All that remains to complete the design of a beam form is to determine the design load for which the form must be designed. Knowing the design load, the maximum allowable bottom sheathing span (shore spacing) for the materials available can be determined. Next the total load per shore can be determined and the design completed with the selection of shore and bracing material that will safely support the vertical and lateral loads. Each of these steps used in beam form design can be accomplished by using the applicable procedures discussed in the previous section on slab form design.

CONCRETE MIXTURES

Constructionman introduces the fundamentals of the ingredients of concrete and of concrete construction. *Builder 3 & 2* provides further details of the characteristics of good concrete and stresses the importance of proper batching, mixing, handling, placing, finishing, and curing. The characteristics of concrete should be considered on a relative basis and in terms of the degree of quality required for a given construction project. Figure 4-9 shows some of the properties of good concrete, their inter-relationships, and various elements which control the properties. A study of this figure points up the relative basis of the characteristics. A single batch of concrete cannot possess the maximum of strength, durability, and economy. For example, entrained air makes handling easier and is therefore conducive to economy; entrained air promotes watertightness; but entrained air makes concrete less dense and thereby reduces the strength. The goal is to achieve an optimum balance of all the elements. A thorough discussion of all the factors involved in the production of good concrete is beyond the scope of this book. There is a wealth of information available to you in government and commercial publications.

The design of or selection of a mix, the necessity for a trial mix, the methods of controlling the mix proportions, and the units of measure to be used in the batching all depend on the nature and size of the job and the extent to which requirements are set forth in specifications or on the plans.

An example of the simplest form of concrete batching is the mixing of a very small amount of concrete using the 1:2:4 carpenter's mix. The relative volumes of cement, sand, and gravel could be measured in bucketfuls, or even in shovelfuls, and sufficient water added to give reasonable consistency. A more refined procedure is to fabricate a one-cubic-foot wooden measuring box to give you greater control over the proportions of the ingredients. To mix approximately one cubic yard of 1:2:4 concrete, you use the Rule of 42:

Cement	4 + 2	6 bags
Sand	2 x 6	12 cubic feet
Gravel	4 x 6	24 cubic feet
		42 cubic feet of material

In addition to the carpenter's mix, there are other popular rule-of-thumb mixes:

1:1:2—a very rich mix—use when great strength is required
1:2:5—a medium mix—use in large slabs and walls
1:3:5—a lean mix—use in large foundations or as a backing for masonry
1:4:8—a very lean mix—use only in mass placings.

To achieve more control over the proportional quantities of cement, water and aggregate for a concrete mix, one of three methods (book, trial batch, or absolute volume) is commonly used.

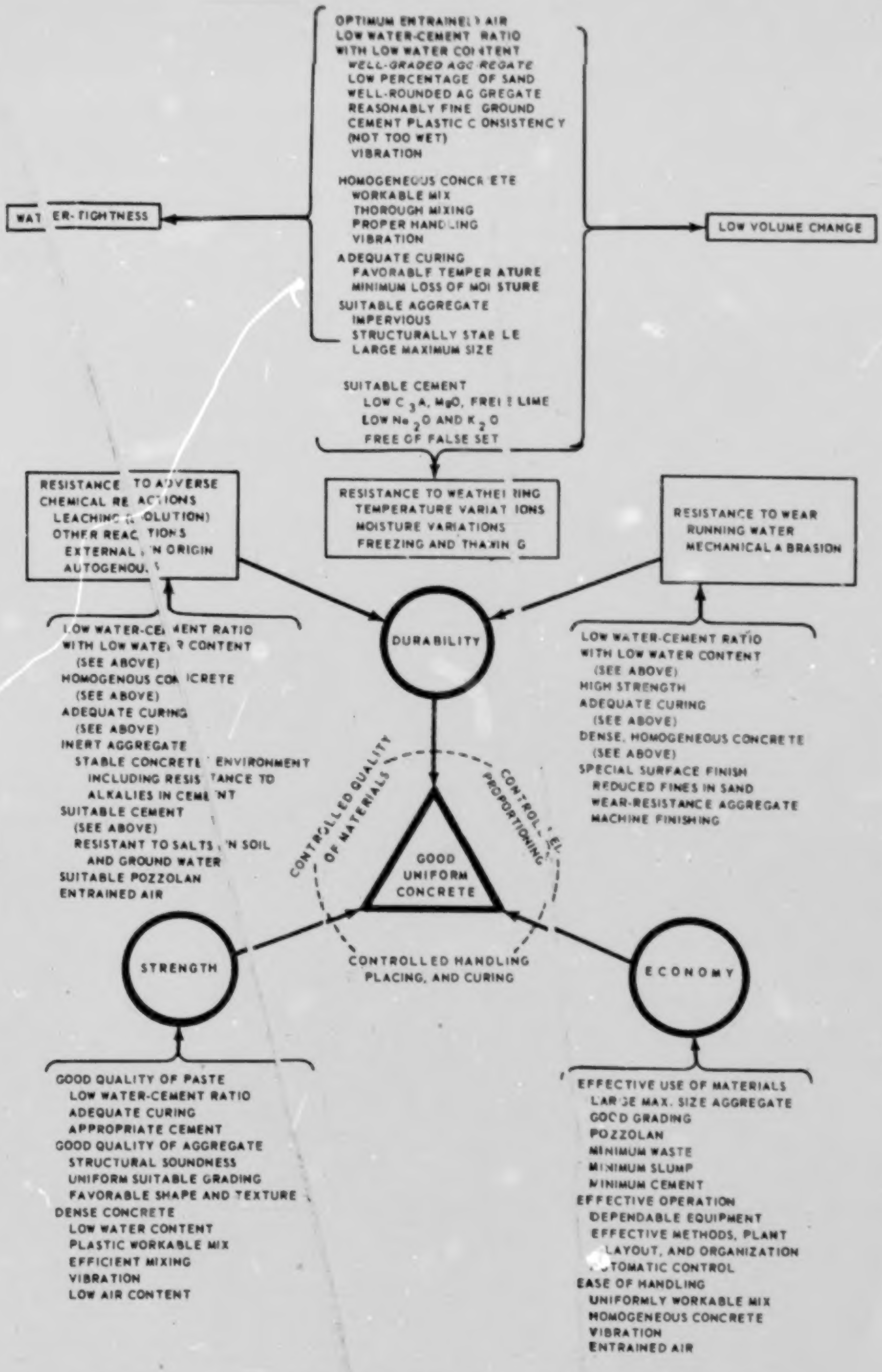
BOOK METHOD

The book method is a theoretical procedure in which established data is used to determine mix proportions. Due to the variation of the materials (aggregates) used, mixes arrived at by the book method require adjustment in the field following the mixing of trial batches and testing. Concrete mixtures should be designed to give the most economical and practical combination of the materials that will produce the necessary workability in the fresh concrete and the required qualities in the hardened concrete.

Selecting Mix Characteristics

Certain information must be known before a concrete mixture can be proportioned. The size and shape of structural members, the concrete strength required, and the exposure conditions must be determined. The water-cement ratio, aggregate characteristics, amount of entrained air, and slump are significant factors in the selection of the appropriate concrete mixture.

WATER-CEMENT RATIO.—In arriving at the water-cement ratio, the requirements of strength, durability, and water-tightness of the hardened concrete must be considered. These factors are usually specified by the engineer in the design of the structure or assumed for purposes of arriving at tentative mix proportions.


OPTIMUM ENTRAINED AIR
LOW WATER-CEMENT RATIO
WITH LOW WATER CONTENT
WELL-GRADED AGGREGATE
LOW PERCENTAGE OF SAND
WELL-ROUNDED AGGREGATE
REASONABLY FINE GROUND
CEMENT PLASTIC CONSISTENCY
(NOT TOO WET)
VIBRATION
HOMOGENEOUS CONCRETE
WORKABLE MIX
THOROUGH MIXING
PROPER HANDLING
VIBRATION
ADEQUATE CURING
FAVORABLE TEMPERATURE
MINIMUM LOSS OF MOISTURE
SUITABLE AGGREGATE
IMPERVIOUS
STRUCTURALLY STABLE
LARGE MAXIMUM SIZE
SUITABLE CEMENT
LOW C_3A, MgO, FREE LIME
LOW Na_2O AND K_2O
FREE OF FALSE SET
WATER-TIGHTNESS
LOW VOLUME CHANGE
RESISTANCE TO ADVERSE CHEMICAL REACTIONS
LEACHING (SOLUTION)
OTHER REACTIONS
EXTERNAL IN ORIGIN
AUTOGENOUS
RESISTANCE TO WEATHERING
TEMPERATURE VARIATIONS
MOISTURE VARIATIONS
FREEZING AND THAWING
RESISTANCE TO WEAR
RUNNING WATER
MECHANICAL ABRASION
LOW WATER-CEMENT RATIO
WITH LOW WATER CONTENT
(SEE ABOVE)
HOMOGENOUS CONCRETE
(SEE ABOVE)
ADEQUATE CURING
(SEE ABOVE)
INERT AGGREGATE
STABLE CONCRETE ENVIRONMENT
INCLUDING RESISTANCE TO
ALKALIES IN CEMENT
SUITABLE CEMENT
(SEE ABOVE)
RESISTANT TO SALTS IN SOIL
AND GROUND WATER
SUITABLE POZZOLAN
ENTRAINED AIR
DURABILITY
LOW WATER-CEMENT RATIO
WITH LOW WATER CONTENT
(SEE ABOVE)
HIGH STRENGTH
ADEQUATE CURING
(SEE ABOVE)
DENSE, HOMOGENEOUS CONCRETE
(SEE ABOVE)
SPECIAL SURFACE FINISH
REDUCED FINES IN SAND
WEAR-RESISTANCE AGGREGATE
MACHINE FINISHING
CONTROLLED QUALITY OF MATERIALS
CONTROLLED PROPORTIONING
GOOD UNIFORM CONCRETE
CONTROLLED HANDLING PLACING, AND CURING
STRENGTH
ECONOMY
GOOD QUALITY OF PASTE
LOW WATER-CEMENT RATIO
ADEQUATE CURING
APPROPRIATE CEMENT
GOOD QUALITY OF AGGREGATE
STRUCTURAL SOUNDNESS
UNIFORM SUITABLE GRADING
FAVORABLE SHAPE AND TEXTURE
DENSE CONCRETE
LOW WATER CONTENT
PLASTIC WORKABLE MIX
EFFICIENT MIXING
VIBRATION
LOW AIR CONTENT
EFFECTIVE USE OF MATERIALS
LARGE MAX. SIZE AGGREGATE
GOOD GRADING
POZZOLAN
MINIMUM WASTE
MINIMUM SLUMP
MINIMUM CEMENT
EFFECTIVE OPERATION
DEPENDABLE EQUIPMENT
EFFECTIVE METHODS, PLANT
LAYOUT, AND ORGANIZATION
AUTOMATIC CONTROL
EASE OF HANDLING
UNIFORMLY WORKABLE MIX
HOMOGENEOUS CONCRETE
VIBRATION
ENTRAINED AIR

117.83

Figure 4-9. —Principal properties of good concrete and their relationship.

It is important to remember that a change in the water-cement ratio changes the characteristics of the hardened concrete. Selection of a suitable water-cement ratio is made from table 4-3 for various exposure conditions. Note that the quantities are the recommended maximum permissible water-cement ratios. As indicated in table 4-3, under certain conditions the water-cement ratio should be selected on the basis of concrete strength. In such cases, if possible, tests should be made with job materials to determine the relationship between water-cement ratio and strength. If laboratory test data or experience records for this relationship cannot be obtained, the necessary water-cement ratio may be estimated from figures 4-10 and 4-11, the lower edge of the applicable strength band curve should be used, and the desired design strength of the concrete should be increased by 15 percent according to ACI requirements. If flexural strength rather than compressive strength is the basis for design, as in pavements, tests should be made to determine the relationship between water-cement ratio and flexural strength. An approximate relationship between flexural and compressive strength is—

$$f'c = \left(\frac{R}{K}\right)^2$$

Table 4-3.—ACI Recommended Maximum Permissible Water-Cement Ratios for Different Types of Structures and Degrees of Exposure

Type of structures	Exposure conditions**					
	Severe wide range in temperature or frequent alternations of freezing and thawing (air-entrained concrete only) (gallons/sack)			Mild temperature rarely below freezing, or rainy, or arid (gallons/sack)		
	In air	At water line or within range of fluctuating water level or spray		In air	At water line or within range of fluctuating water level or spray	
		In fresh water	In sea water or in contact with sulfates†		In fresh water	In sea water or in contact with sulfates†
A. Thin sections such as reinforced piles and pipe	5.5	5	4.5	6	5.5	4.5
B. Bridge decks	5	5	4.5	5.5	5.5	5
C. Thin sections such as railings, curbs, sills, ledges, ornamental or architectural concrete, and all sections with less than 1-in. concrete cover over reinforcement	5.5			6	5.5	
D. Moderate sections, such as retaining walls, abutments, piers, girders, beams	6	5.5	5	††	6	5
E. Exterior portions of heavy (mass) sections	6.5	5.5	5	††	6	5
F. Concrete deposited by tremie under water		5	5		5	5
G. Concrete slabs laid on the ground	6			††		
H. Pavements	5.5			6		
I. Concrete protected from the weather, interiors of buildings, concrete below ground	††			††		
J. Concrete which will later be protected by enclosure or backfill but which may be exposed to freezing and thawing for several years before such protection is offered	6			††		

*Adapted from Recommended Practice for Selecting Proportions for Concrete (ACI 613-54).

**Air-entrained concrete should be used under all conditions involving severe exposure and may be used under mild exposure conditions to improve workability of the mixture.

†Soil or groundwater containing sulfate concentrations of more than 0.2 per cent. For moderate sulfate resistance, the tricalcium aluminate content of the cement should be limited to 8 per cent, and for high-sulfate resistance to 5 per cent. At equal cement contents, air-entrained concrete is significantly more resistant to sulfate attack than non-air-entrained concrete.

††Water-cement ratio should be selected on basis of strength and workability requirements, but minimum cement content should not be less than 470 lb. per cubic yard.

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where f'c = compressive strength, in psi
R = flexural strength (modulus of rupture), in psi, third-point loading
K = a constant, usually between 8 and 10.

In cases where both exposure conditions and strength must be considered, the lower of the two indicated water-cement ratios should be used.

AGGREGATE CHARACTERISTICS.–The aggregate shape, surface texture and soundness influence the properties of both fresh and hardened concrete. In fresh concrete it will influence the workability of the mix. In hardened concrete it affects the durability and strength. Very sharp and rough aggregate particles or flat elongated particles require more fine material to fill the voids and produce a workable mix, than do particles that are partially rounded or cubicle. Stones which break up into long

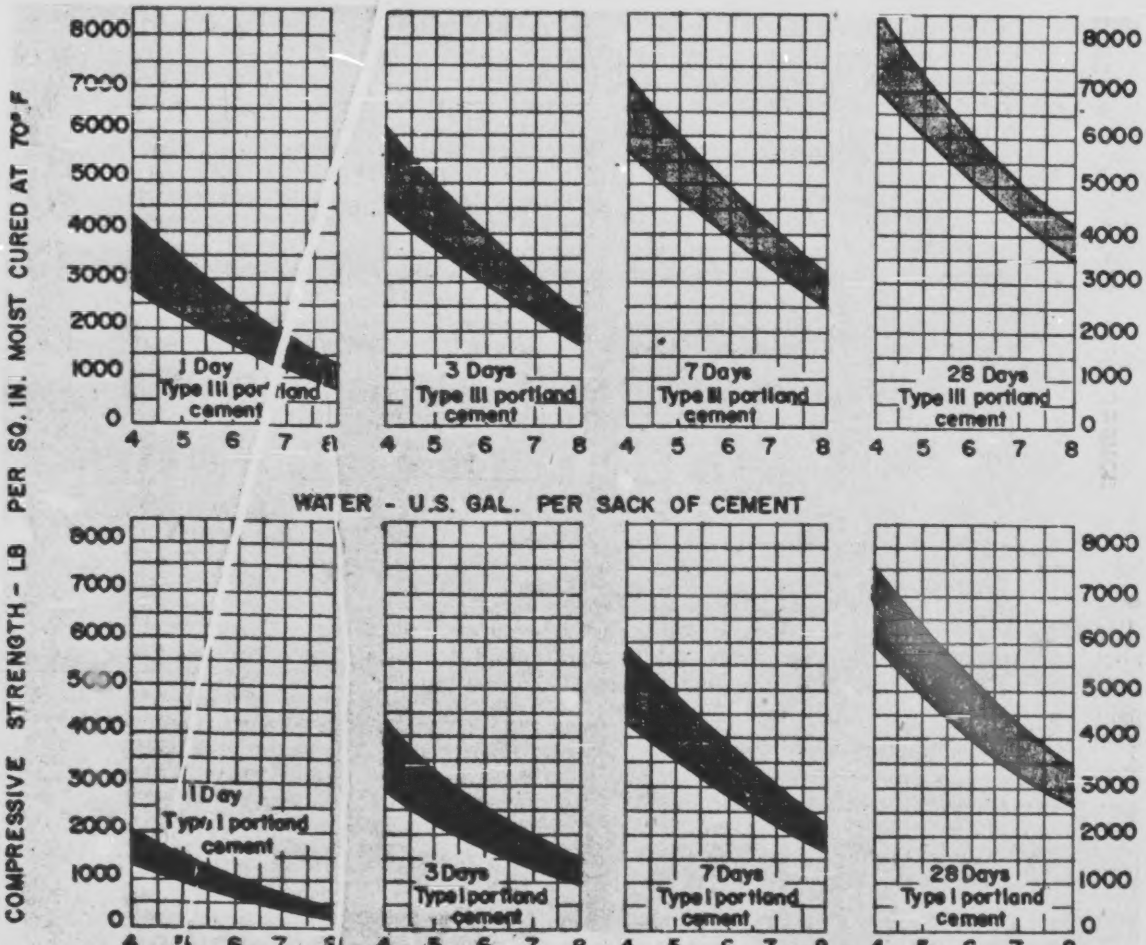

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Figure 4-10. –Age-compressive strength relationship for types I and III non-air-entrained portland cement.

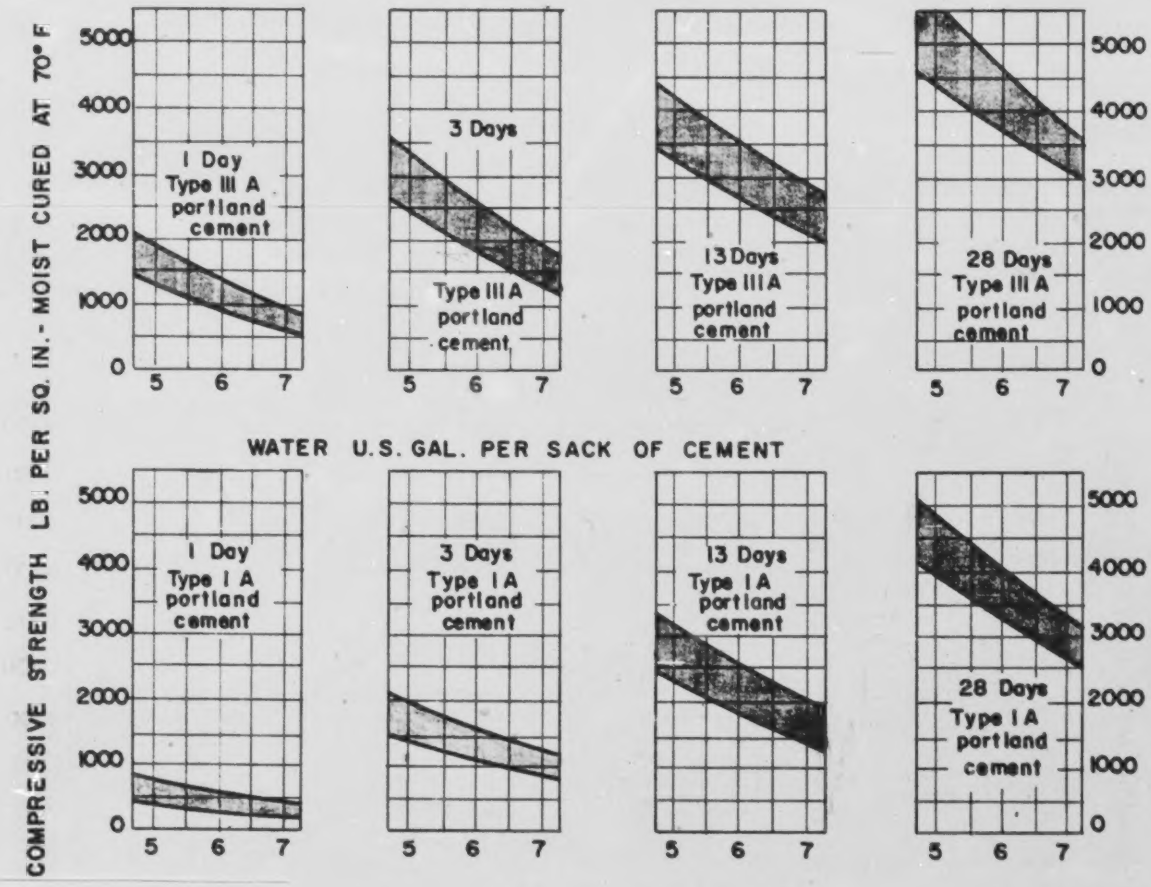

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Figure 4-11. —Age-compressive strength relationships for types I and III air-entrained portland cement.

slivery pieces should be avoided or limited to about 15 percent in aggregate. Flat pieces of aggregate are particularly objectionable in pavement or slabs because when they lie near the surface heavy loads may break them out leaving shallow cavities or voids in the concrete.

The grading and maximum size of aggregate are important because of their relative effect on the durability, strength, and economy of concrete as shown in figure 4-9.

Fine aggregate fills the spaces in the course aggregate and increases the workability of the mix. In general, aggregates which do not have a large deficiency or an excess of any size and give a smooth grading curve produce the most satisfactory mix.

The largest size coarse aggregate which is practical should be used. The larger the maximum size of the coarse aggregate, the less mortar and paste will be necessary. It follows that the larger the coarse aggregate, the less water and cement will be required for a given quality of concrete. The maximum size aggregate should not exceed one-fifth the minimum dimension of the member, or three-fourths of the clear space between reinforcing bars. For pavement or floor slabs, the maximum size aggregate should not exceed one-third the slab thickness. The maximum size of coarse aggregate that produces concrete of maximum strength for a given cement content depends upon aggregate source as well as aggregate shape and grading. For many aggregates, this "optimum" maximum size is about 3/4 inch. However, a maximum size of 1-1/2 aggregate is satisfactory for use in pavements.

ENTRAINED AIR.–Entrained air should be used in all concrete exposed to freezing and thawing and may be used for mild exposure conditions to improve workability. It is recommended for all paving concrete regardless of climatic conditions. The recommended total air contents for air-entrained concretes are shown in table 4-4. When mixing water is held constant, the entrainment of air will increase slump. When cement content and slump are held constant, less mixing water is required; the resulting decrease in the water-cement ratio helps to offset possible strength decreases and results in improvements in other paste properties such as permeability. Hence, the strength of air-entrained concrete may equal, or nearly equal, that of non-air-entrained concrete when their cement contents and slumps are the same.

SLUMP.–The slump test is generally used as a measure of the consistency of concrete. It should not be used to compare mixes with wholly different proportions or mixes with different kinds of sizes of aggregates. When used to test different batches of the same mixture, changes in slump indicate changes in materials, mix proportions, or water content. Acceptable slump ranges are indicated in table 4-5.

MIX PROPORTIONS.–Knowing the water-cement ratio, slump, maximum size of aggregate, and fineness modulus, tables of trial mixes such as tables 4-6 and 4-7 can be used to determine the proportions of trial mixes. The quantities in tables 4-6 and 4-7 are based on concrete having a slump of 3 to 4 inches, with well graded aggregates having a specific gravity of 2.65. For other conditions it is necessary to adjust the quantities in accordance with the footnotes.

Determining Mix Proportions

The mix proportions are to be determined for a water-cement ratio of 6 gallons per sack, maximum aggregate size of 1 inch, air content of 6 ± 1 percent, and a slump of 3 to 4 inches. The fine aggregate has a fineness modulus of 2.50 and a moisture content of 5 percent. The coarse aggregate has a moisture content of 1 percent.

Table 4-7 for air-entrained concrete will be used because of the air content requirement.

Table 4-4.–Approximate Mixing Water Requirements for Different Slumps and Maximum Sizes of Aggregates

Maximum size of aggregate, in.	Air-entrained concrete				Non-air-entrained concrete			
	Recommended average total air content, per cent†	Slump, in.			Approximate amount of entrapped air, per cent	Slump, in.		
		1 to 2	3 to 4	5 to 6		1 to 2	3 to 4	5 to 6
		Water, gal. per cu.yd. of concrete**				Water, gal. per cu.yd. of concrete**		
3/8	7.5	37	41	43	3.0	42	46	49
1/2	7.5	36	39	41	2.5	40	44	46
3/4	6.0	33	36	38	2.0	37	41	43
1	6.0	31	34	36	1.5	36	39	41
1 1/2	5.0	29	32	34	1.0	33	36	38
2	5.0	27	30	32	0.5	31	34	36
3	4.0	25	28	30	0.3	29	32	34
6	3.0	22	24	26	0.2	25	28	30

*Adapted from Recommended Practice for Selecting Proportions for Concrete (ACI 613-54).

**These quantities of mixing water are for use in computing cement factors for trial batches. They are maximums for reasonably well-shaped angular coarse aggregates graded within limits of accepted specifications.

†Plus or minus 1 per cent.

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Table 4-5.–Recommended Slumps for Various Types of Construction

Type of construction	Slump, inches	
	Maximum	Minimum
Reinforced foundation walls and footings	6	3
Unreinforced footings, caissons, and substructure walls	4	1
Reinforced slabs, beams, and walls	6	3
Building columns	6	4
Pavements	3	1
Heavy mass construction	3	1
Bridge decks	4	3
Sidewalk, driveway, and slabs on ground	6	3

*When high-frequency vibrators are used, the values may be decreased approximately one-third, but in no case should the slump exceed 6 inches.

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The following quantities per cubic yard are taken from table 4-7:

Cement	5.7 sacks =	535 pounds
Water	34 gallons =	285 pounds
Fine aggregate		1,040 pounds
Coarse aggregate		1,940 pounds
Total		3,800 pounds

The moisture content of the aggregates must be considered since the tables are for the saturated, surface-dry condition. The free moisture in the fine aggregate is 5 percent of 1,040 pounds or 52 pounds (use 50 pounds). The free moisture in the coarse aggregate is 1 percent of 1,940 pounds or approximately 19 pounds (use 20 pounds). The corrected weights per cubic yard of concrete are–

Cement		535 pounds
Water	285 – 50 – 20 =	215 pounds
Fine aggregate	1,040 + 50	= 1,090 pounds
Coarse aggregate	1,940 + 20	= 1,960 pounds
Total		3,800 pounds

When these quantities were mixed, the consistency was such that the slump was approximately 1 inch. Additional water (25 pounds) was added to bring the slump to slightly more than 3 inches. The unit weight was measured to be 145 pounds per cubic foot. Since the unit weight of the concrete was 145 pounds per cubic foot and the total weight of concrete was 3,800 + 25 = 3,825 pounds, the volume of concrete was 26.4 cubic feet. This is slightly less than 1 cubic yard (27 cubic feet). The principal reason for this discrepancy is that the specific gravity values of the aggregates were probably different from those assumed in tables 4-6 and 4-7. In small adjustments it may be assumed that the unit weight of the concrete remains essentially constant and that the amount of water required per cubic yard of concrete remains constant. The adjusted water requirement is–

$$\frac{27}{26.4} \times 310 \text{ pounds} = 315 \text{ pounds} = 38 \text{ gallons}$$

Note that the 310 pounds used is the total amount of water needed, 285 + 25 pounds. The adjusted cement requirement is

$$\frac{38 \text{ gallons}}{6 \ \frac{\text{gallons}}{\text{sack}}} = 6.3 \text{ sacks} = 595 \text{ pounds}$$

The weight of materials per cubic yard of concrete must total 145 x 27 = 3,910 pounds, approximately. The total weight of aggregates must therefore be 3,910 - 315 - 595 = 3,000 pounds. Table 4-7 indicates that 35 percent of this should be fine aggregate.

The adjusted trial mix proportions (per cubic yard) are therefore:

Cement	6.3	sacks
Water	38	gallons
Fine aggregate	1,050	pounds
Coarse aggregate	1,950	pounds

TRIAL BATCH METHOD

The trial batch method of mix design utilizes the actual materials in arriving at mix proportions instead of the tables of trial mixes (tables 4-6 and 4-7). When the quality of the concrete mixture is specified in terms of the water-cement ratio, the trial batch procedure consists

Table 4-6.—Suggested Trial Mixes for Non-Air-Entrained Concrete of Medium Consistency with 3- to 4-Inch Slump

Water-cement ratio Gal per sack	Maximum size of aggregate inches	Air content (entrapped air) per cent	Water gal per cu yd of concrete	Cement sacks per cu yd of concrete	With fine sand—fineness modulus = 2.50		
					Fine aggregate per cent of total aggregate	Fine aggregate lb per cu yd of concrete	Coarse aggregate lb per cu yd of concrete
4.5	⅜	3	46	10.3	50	1240	1260
	½	2.5	44	9.8	42	1100	1520
	¾	2	41	9.1	35	960	1800
	1	1.5	39	8.7	32	910	1940
	1½	1	36	8.0	29	880	2110
5.0	⅜	3	46	9.2	51	1330	1260
	½	2.5	44	8.8	44	1180	1520
	¾	2	41	8.2	37	1040	1800
	1	1.5	39	7.8	34	990	1940
	1½	1	36	7.2	31	960	2110
5.5	⅜	3	46	8.4	52	1390	1260
	½	2.5	44	8.0	45	1240	1520
	¾	2	41	7.5	38	1090	1800
	1	1.5	39	7.1	35	1040	1940
	1½	1	36	6.5	32	1000	2110
6.0	⅜	3	46	7.7	53	1440	1260
	½	2.5	44	7.3	46	1290	1520
	¾	2	41	6.8	39	1130	1800
	1	1.5	39	6.5	36	1080	1940
	1½	1	36	6.0	33	1040	2110
6.5	⅜	3	46	7.1	54	1480	1260
	½	2.5	44	6.8	46	1320	1520
	¾	2	41	6.3	39	1190	1800
	1	1.5	39	6.0	37	1120	1940
	1½	1	36	5.5	34	1070	2110
7.0	⅜	3	46	6.6	55	1520	1260
	½	2.5	44	6.3	47	1360	1520
	¾	2	41	5.9	40	1200	1800
	1	1.5	39	5.6	37	1150	1940
	1½	1	36	5.1	34	1100	2110
7.5	⅜	3	46	6.1	55	1560	1260
	½	2.5	44	5.9	48	1400	1520
	¾	2	41	5.5	41	1240	1800
	1	1.5	39	5.2	38	1190	1940
	1½	1	36	4.8	35	1130	2110
8.0	⅜	3	46	5.7	56	1600	1260
	½	2.5	44	5.5	48	1440	1520
	¾	2	41	5.1	42	1280	1800
	1	1.5	39	4.9	39	1220	1940
	1½	1	36	4.5	35	1160	2110

*See footnote at end of table.

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Table 4-6.–Suggested Trial Mixes for Non-Air-Entrained Concrete of Medium Consistency with 3- to 4-Inch Slump–continued

With average sand—fineness modulus = 2.75			With coarse sand—fineness modulus = 2.90		
Fine aggregate percent of total aggregate	Fine aggregate lb per cu yd of concrete	Coarse aggregate lb per cu yd of concrete	Fine aggregate percent of total aggregate	Fine aggregate lb per cu yd of concrete	Coarse aggregate lb per cu yd of concrete
52	1310	1190	54	1350	1150
45	1170	1450	47	1220	1400
37	1030	1730	39	1080	1680
34	980	1870	36	1020	1830
32	960	2030	33	1000	1990
54	1400	1190	56	1440	1150
46	1250	1450	48	1300	1400
39	1110	1730	41	1160	1680
36	1060	1870	38	1100	1830
34	1040	2030	35	1080	1990
55	1460	1190	57	1500	1150
47	1310	1450	49	1360	1400
40	1160	1730	42	1210	1680
37	1110	1870	39	1150	1830
35	1080	2030	36	1120	1990
56	1510	1190	57	1550	1150
48	1360	1450	50	1410	1400
41	1200	1730	43	1250	1600
38	1150	1870	39	1190	1830
36	1120	2030	37	1160	1990
57	1550	1190	58	1590	1150
49	1390	1450	51	1440	1400
42	1240	1730	43	1290	1680
39	1190	1870	40	1230	1830
36	1150	2030	37	1190	1990
57	1590	1190	59	1630	1150
50	1430	1450	51	1480	1400
42	1270	1730	44	1320	1680
39	1220	1870	41	1260	1830
37	1180	2030	38	1220	1990
58	1630	1190	59	1670	1150
50	1470	1450	52	1520	1400
43	1310	1730	45	1370	1600
40	1260	1870	42	1300	1830
37	1210	2030	39	1250	1990
58	1670	1190	60	1710	1150
51	1520	1450	53	1560	1400
44	1350	1730	45	1400	1680
41	1290	1870	42	1330	1830
38	1250	2030	39	1280	1990

*Increase or decrease water per cubic yard by 3 per cent for each increase or decrease of 1 in. in slump, then calculate quantities by absolute volume method. For manufactured fine aggregate, increase percentage of fine aggregate by 3 and water by 17 lb. per cubic yard of concrete. For less workable concrete, as in pavements, decrease percentage of fine aggregate by 3 and water by 8 lb. per cubic yard of concrete.

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Table 4-7.—Suggested Trial Mixes for Air-Entrained Concrete of Medium Consistency with 3- to 4-Inch Slump

Water-cement ratio Gal per sack	Maximum size of aggregate inches	Air Content (entrapped air) per cent	Water gal per cu yd of concrete	Cement sacks per cu yd of concrete	With fine sand—fineness modulus = 2.50		
					Fine aggregate per cent of total aggregate	Fine aggregate lb per cu yd of concrete	Coarse aggregate lb per cu yd of concrete
4.5	⅜	7.5	41	9.1	50	1250	1260
	½	7.5	39	8.7	41	1060	1520
	¾	6	36	8.0	35	970	1800
	1	6	34	7.8	32	900	1940
	1½	5	32	7.1	29	870	2110
5.0	⅜	7.5	41	8.2	51	1330	1260
	½	7.5	39	7.8	43	1140	1520
	¾	6	36	7.2	37	1040	1800
	1	6	34	6.8	33	970	1940
	1½	5	32	6.4	31	930	2110
5.5	⅜	7.5	41	7.5	52	1390	1260
	½	7.5	39	7.1	44	1190	1520
	¾	6	36	6.5	38	1090	1800
	1	6	34	6.2	34	1010	1940
	1½	5	32	5.8	32	970	2110
6.0	⅜	7.5	41	6.8	53	1430	1260
	½	7.5	39	6.5	45	1230	1520
	¾	6	36	6.0	38	1120	1800
	1	6	34	5.7	35	1040	1940
	1½	5	32	5.3	32	1010	2110
6.5	⅜	7.5	41	6.3	54	1460	1260
	½	7.5	39	6.0	45	1260	1520
	¾	6	36	5.5	39	1150	1800
	1	6	34	5.2	36	1080	1940
	1½	5	32	4.9	33	1040	2110
7.0	⅜	7.5	41	5.9	54	1500	1260
	½	7.5	39	5.6	46	1300	1520
	¾	6	36	5.1	40	1180	1800
	1	6	34	4.9	36	1100	1940
	1½	5	32	4.6	33	1060	2110
7.5	⅜	7.5	41	5.5	55	1530	1260
	½	7.5	39	5.2	47	1330	1520
	¾	6	36	4.8	40	1210	1800
	1	6	34	4.5	37	1140	1940
	1½	5	32	4.3	34	1090	2110
8.0	⅜	7.5	41	5.1	55	1560	1260
	½	7.5	39	4.9	47	1360	1520
	¾	6	36	4.5	41	1240	1800
	1	6	34	4.3	37	1160	1940
	1½	5	32	4.0	34	1110	2110

*See footnote at end of table.

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Table 4-7.–Suggested Trial Mixes for Air-Entrained Concrete of Medium Consistency with 3- to 4-Inch Slump–continued

With average sand—fineness modulus = 2.75			With coarse sand—fineness modulus = 2.90		
Fine aggregate percent of total aggregate	Fine aggregate lb per cu yd of concrete	Coarse aggregate lb per cu yd of concrete	Fine aggregate percent of total aggregate	Fine aggregate lb per cu yd of concrete	Coarse aggregate lb per cu yd of concrete
53	1320	1190	54	1360	1150
44	1130	1450	46	1180	1400
38	1040	1730	39	1090	1680
34	970	1870	36	1010	1830
32	950	2030	33	990	1990
54	1400	1190	56	1440	1150
46	1210	1450	47	1260	14000
39	1110	1730	41	1160	1630
36	1040	1870	37	1080	1830
33	1010	2030	35	1050	1990
55	1460	1190	57	1500	1150
46	1260	1450	48	1310	1400
40	1160	1730	42	1210	1680
37	1080	1870	38	1120	1830
34	1050	2030	35	1090	1990
56	1500	1190	57	1540	1150
47	1300	1450	49	1350	1400
41	1190	1730	42	1240	1680
37	1110	1870	39	1150	1830
35	1090	2030	36	1130	1990
56	1530	1190	58	1570	1150
48	1330	1450	50	1380	1400
41	1220	1730	43	1270	1680
38	1150	1870	39	1190	1830
36	1120	2030	37	1160	1990
57	1570	1190	58	1610	1150
49	1370	1450	50	1420	1400
42	1250	1730	44	1300	1680
38	1170	1870	40	1210	1830
36	1140	2030	37	1180	1990
57	1600	1190	59	1640	1150
49	1400	1450	51	1450	1400
43	1280	1730	44	1330	1680
39	1210	1870	41	1250	1830
37	1170	2030	38	1210	1990
58	1630	1190	59	1670	1150
50	1430	1450	51	1480	1400
43	1310	1730	44	1360	1680
40	1230	1870	41	1270	1830
37	1190	2030	38	1230	1990

*Increase or decrease water per cubic yard by 3 per cent for each increase or decrease of 1 in. in slump, then calculate quantities by absolute volume method For manufactured fine aggregate, increase percentage of fine aggregate by 3 and water by 17 lb. per cubic yard of concrete. For less workable concrete, as in pavements decrease percentage of fine aggregate by 3 and water by 8 lb. per cubic yard of concrete.

essentially of combining a paste (water, cement, and, generally, entrained air) of the correct proportions with the necessary amounts of fine and coarse aggregates to produce the required slump and workability. Quantities per sack and/or per cubic yard are then calculated. It is important to use representative samples of the aggregates, cement, water, and air-entrained admixture (if used). The aggregates should be pre-wetted; allowed to dry to a saturated, surface-dry condition; and placed in covered containers to keep them in this condition until used. This procedure simplifies calculations and eliminates error caused by variations in aggregate moisture content. The size of the trial batch is dependent on the equipment and the test specimens to be made. Batches using 10 to 20 pounds of cement may be adequate, although larger batches will produce more accurate data. Machine mixing is recommended since it more nearly represents job conditions; it is mandatory if the concrete is to contain entrained air.

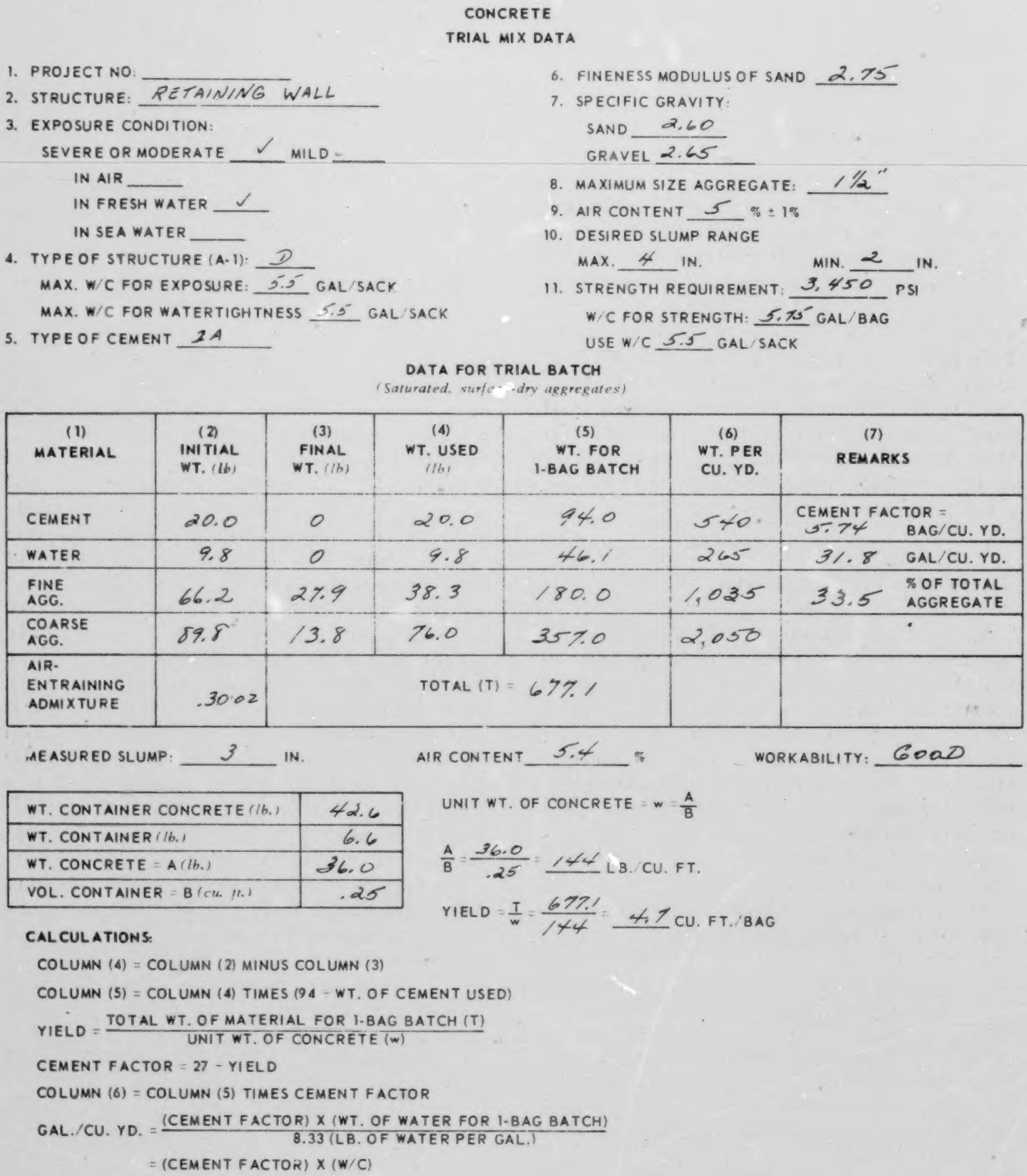
Determining Mix Proportions

The mix proportions are to be determined for concrete which will be used in a retaining wall that will be exposed to fresh water in a severe climate. A compressive strength of 3,000 psi at 28 days is required. The minimum thickness of the wall is 8 inches and 2 inches of concrete must cover the reinforcement. All trial mix data will be entered in the appropriate blanks on the trial mix data worksheet, figure 4-12.

Line D of table 4-3 indicates that a maximum water-cement ratio of 5.5 gallons per sack will satisfy the exposure requirements. Using type IA (air-entrained) portland cement and a compressive strength of 3,450 psi (3,000 psi + 15 percent), figure 4-11 indicates that a maximum water-cement ratio of approximately 5.75 gallons per sack will satisfy the strength requirements. In order to meet both specifications a water-cement ratio of 5.5 gallons per sack is selected. Since the maximum size of coarse aggregate must not exceed one-fifth the minimum thickness of the wall, nor three-fourths of the clear space between reinforcement and the surfaces, the maximum size of coarse aggregate is chosen as 1-1/2 inches. Because of the severe exposure conditions, the concrete should contain entrained air. From table 4-4, the recommended air content is 5 ± 1 percent. If we assume that the concrete will be consolidated by vibration, table 4-5 indicates a recommended slump of from 2 to 4 inches. The trial batch proportions are now determined. A batch containing 20 pounds of cement is chosen for convenience. The mixing water required is therefore

$$\frac{20}{94} \text{ x } 5.5 \frac{\text{gal}}{\text{sack}} \text{ x } 8.33 \frac{\text{lb}}{\text{gal}} = 9.8 \text{ pounds}$$

Representative samples of fine and coarse aggregates are selected and weighed. This is recorded in column (2) of figure 4-12. All of the measured quantities of cement, water, and air-entraining admixture are used. Fine and coarse aggregates are then added until a workable mixture having the proper slump is produced. Figure 4-13 indicates the appearance of fresh concrete with correct and incorrect amounts of mortar. The weight of material actually used is recorded in column (4). The weight for a 1-bag batch and per cubic yard are calculated and recorded in columns (5) and (6), respectively. The cement factor in bags per cubic yard is calculated and recorded as indicated in figure 4-12. The percentage of fine aggregate by weight of total aggregate is also included as is the yield of concrete in cubic feet per bag. The slump, air content, workability, and unit weight of concrete are determined and noted as shown. To determine the most economical proportions, additional trial batches should be made varying the percentage of fine aggregate. In each batch the water-cement ratio, aggregate gradations, air content, and slump are maintained approximately the same. Results of four such trial batches are summarized in table 4-8. For these mixes, the percentage of fine aggregate is plotted against the cement factor in figure 4-14. The minimum cement factor (5.72 sacks per cubic yard, use 5.7) occurs at a fine aggregate content of about 32 percent of total aggregate. Since the water-cement ratio is 5.5 gallons per sack and the unit weight of the concrete for an air content of 5 percent is about 144 pounds per



CONCRETE
TRIAL MIX DATA

1. PROJECT NO: ________
2. STRUCTURE: RETAINING WALL
3. EXPOSURE CONDITION:
   SEVERE OR MODERATE ✓ MILD ____
   IN AIR ____
   IN FRESH WATER ✓
   IN SEA WATER ____
4. TYPE OF STRUCTURE (A-1): D
   MAX. W/C FOR EXPOSURE: 5.5 GAL/SACK
   MAX. W/C FOR WATERTIGHTNESS 5.5 GAL/SACK
5. TYPE OF CEMENT 2A

6. FINENESS MODULUS OF SAND 2.75
7. SPECIFIC GRAVITY:
   SAND 2.60
   GRAVEL 2.65
8. MAXIMUM SIZE AGGREGATE: 1½"
9. AIR CONTENT 5 % ± 1%
10. DESIRED SLUMP RANGE
    MAX. 4 IN. MIN. 2 IN.
11. STRENGTH REQUIREMENT: 3,450 PSI
    W/C FOR STRENGTH: 5.75 GAL/BAG
    USE W/C 5.5 GAL/SACK

DATA FOR TRIAL BATCH
(Saturated, surface-dry aggregates)

(1) MATERIAL	(2) INITIAL WT. *(lb)*	(3) FINAL WT. *(lb)*	(4) WT. USED *(lb)*	(5) WT. FOR 1-BAG BATCH	(6) WT. PER CU. YD.	(7) REMARKS
CEMENT	20.0	0	20.0	94.0	540	CEMENT FACTOR = 5.74 BAG/CU. YD.
WATER	9.8	0	9.8	46.1	265	31.8 GAL/CU. YD.
FINE AGG.	66.2	27.9	38.3	180.0	1,035	33.5 % OF TOTAL AGGREGATE
COARSE AGG.	89.8	13.8	76.0	357.0	2,050	
AIR-ENTRAINING ADMIXTURE	.30 oz	TOTAL (T) = 677.1				

MEASURED SLUMP: 3 IN. AIR CONTENT 5.4 % WORKABILITY: GOOD

WT. CONTAINER CONCRETE *(lb.)*	42.6
WT. CONTAINER *(lb.)*	6.6
WT. CONCRETE = A *(lb.)*	36.0
VOL. CONTAINER = B *(cu. ft.)*	.25

UNIT WT. OF CONCRETE = $w = \frac{A}{B}$

$\frac{A}{B} = \frac{36.0}{.25} = 144$ LB./CU. FT.

YIELD $= \frac{T}{w} = \frac{677.1}{144} = 4.7$ CU. FT./BAG

CALCULATIONS:

COLUMN (4) = COLUMN (2) MINUS COLUMN (3)

COLUMN (5) = COLUMN (4) TIMES (94 ÷ WT. OF CEMENT USED)

$$\text{YIELD} = \frac{\text{TOTAL WT. OF MATERIAL FOR 1-BAG BATCH (T)}}{\text{UNIT WT. OF CONCRETE (w)}}$$

CEMENT FACTOR = 27 ÷ YIELD

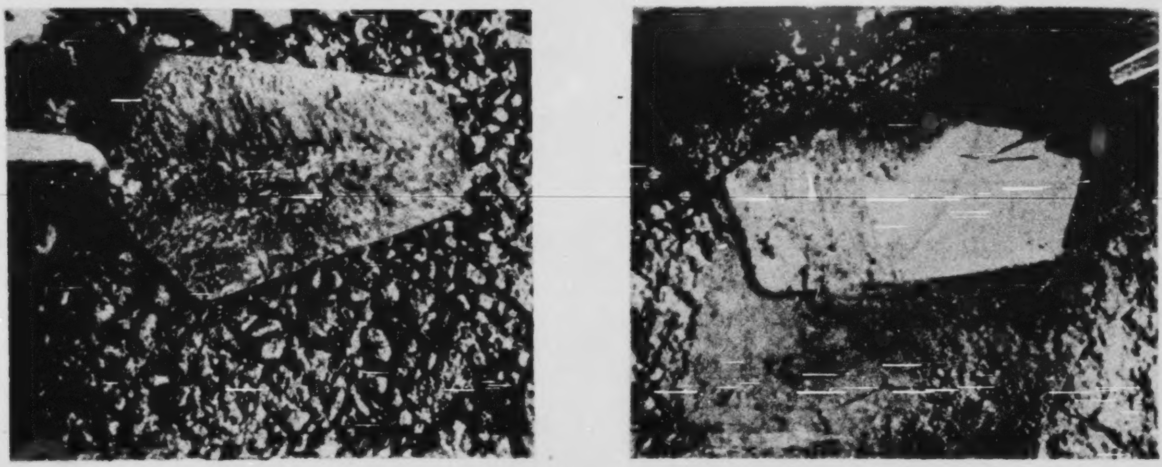
COLUMN (6) = COLUMN (5) TIMES CEMENT FACTOR

$$\text{GAL./CU. YD.} = \frac{\text{(CEMENT FACTOR) X (WT. OF WATER FOR 1-BAG BATCH)}}{\text{8.33 (LB. OF WATER PER GAL.)}}$$

= (CEMENT FACTOR) X (W/C)

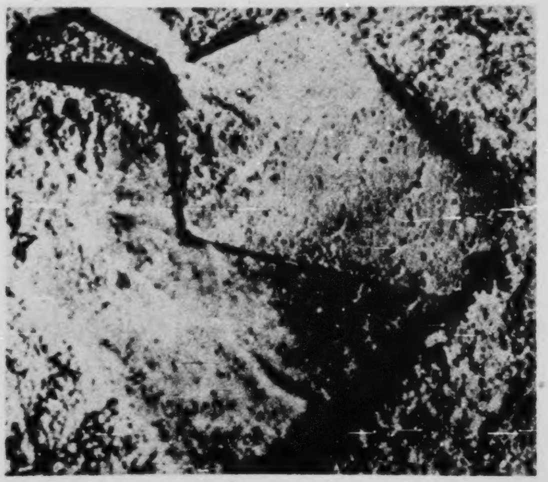
117.345

Figure 4-12. –Worksheet for concrete trial mix data.



(A) A CONCRETE MIXTURE IN WHICH THERE IS NOT SUFFICIENT CEMENT-SAND MORTAR TO FILL ALL THE SPACES BETWEEN COARSE AGGREGATE PARTICLES. SUCH A MIXTURE WILL BE DIFFICULT TO HANDLE AND PLACE AND WILL RESULT IN ROUGH, HONEYCOMBED SURFACE AND POROUS CONCRETE.

(B) A CONCRETE MIXTURE WHICH CONTAINS CORRECT AMOUNT OF CEMENT-SAND MORTAR. WITH LIGHT TROWELING ALL SPACES BETWEEN COARSE AGGREGATE PARTICLES ARE FILLED WITH MORTAR. NOTE APPEARANCE ON EDGES OF PILE. THIS IS A GOOD WORKABLE MIXTURE AND WILL GIVE MAXIMUM YIELD OF CONCRETE WITH A GIVEN AMOUNT OF CEMENT.



(C) A CONCRETE MIXTURE IN WHICH THERE IS AN EXCESS OF CEMENT-SAND MORTAR. WHILE SUCH A MIXTURE IS PLASTIC AND WORKABLE AND WILL PRODUCE SMOOTH SURFACES, THE YIELD OF CONCRETE WILL BE LOW AND CONSEQUENTLY UNECONOMICAL. SUCH CONCRETE IS ALSO LIKELY TO BE POROUS.

117.346

Figure 4-13. —Appearance of concrete mixes with correct and incorrect amounts of mortar.

Table 4-8.–Examples of Results of Laboratory Trial Mixes

Batch no.	Slump, in.	Air content, per cent	Unit wt., pcf	Cement factor, sacks per cu. yd.	Fine aggregate, per cent of total aggregate	Work-ability
1	3	5.4	144	5.74	33.5	Excellent
2	2¾	4.9	144	5.91	27.4	Harsh
3	2½	5.1	144	5.84	35.5	Excellent
4	3¼	4.7	145	5.74	30.5	Good

*The water-cement ratio selected was 5.5 gal/sack.

117.347

cubic foot, the final quantities for the mix proportions (per cubic yard) are–

Cement	5.7 sacks	=	535 pounds
Water	5.7 sacks x 5.5 gal/sack 31.5 gallons	=	260 pounds
	Total		795 pounds

Concrete per cub yard	144 x 27	= 3,890 pounds
Aggregates	3,890 – 795	= 3,095 pounds
Fine aggregate	.32 x 3,095	= 990 pounds
Coarse aggregate	3,095 – 990	= 2,105 pounds

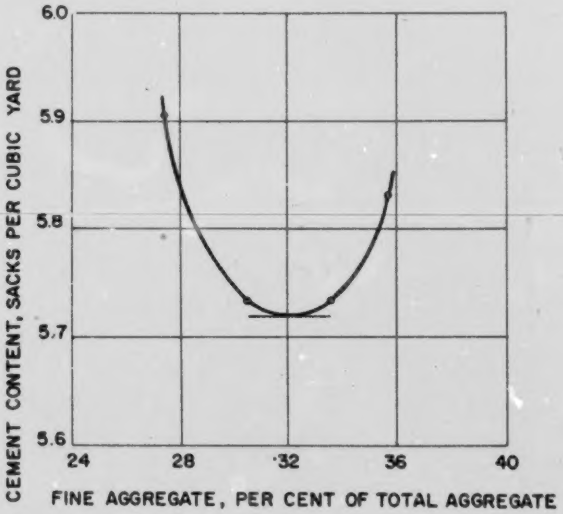


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Figure 4-14.–Relationship between percentage of fine aggregate and cement content for a given water-cement ratio and slump.

ABSOLUTE VOLUME METHOD

Concrete mixtures may be proportioned by using absolute volumes. This method is detailed in the American Concrete Institute (ACI) report, Recommended Practice for Selecting Proportions for Concrete (ACI 613-54). In this method, the water-cement ratio, slump, air content, and maximum size of aggregate are selected as before. In addition, the water requirement is estimated from table 4-4. Certain additional items must be known before calculations can be made. These are: the specific gravities of fine and coarse aggregates, the dry-rodded unit weight of coarse aggregate, and the fineness modulus of the fine aggregate. If the maximum size of aggregate and the fineness modulus of the fine aggregate are known, the volume of dry-rodded coarse aggregate per cubic yard can be estimated from table 4-9. Then the quantities per cubic yard of water, cement, coarse aggregate, and air can be calculated. The sum of the absolute volumes of these materials in cubic feet is then subtracted from 27 to give the specific volume of fine aggregate.

Determining Mix Proportions

The mix proportions are to be determined for the following conditions:

Maximum water-cement ratio	5.5 gallons per sack
Maximum size of aggregate	3/4 inch
Air content	6 ± 1 percent
Slump	2 to 3 inches
Fineness modulus of fine aggregate	2.75
Specific gravity of portland cement	3.15
Specific gravity of fine aggregate	2.66
Specific gravity of coarse aggregate	2.61
Dry-rodded unit weight of coarse aggregate	104 pounds per cubic foot

Table 4-9.—Volume of Coarse Aggregate Per Cubic Yard of Concrete

Maximum size of aggregate, in.	Fineness modulus of fine aggregate			
	2.40	2.60	2.80	3.00
	Coarse aggregate, cu. ft. per cu. yd.*			
3/8	13.5	13.0	12.4	11.9
1/2	15.9	15.4	14.8	14.3
3/4	17.8	17.3	16.7	16.2
1	19.2	18.6	18.1	17.6
1 1/2	20.2	19.7	19.2	18.6
2	21.1	20.5	20.0	19.4
3	22.1	21.6	21.1	20.5

*Volumes are based on aggregates in dry-rodded condition as described in Method of Test for Unit Weight of Aggregate (ASTM C29). These volumes are selected from empirical relationships to produce concrete with a degree of workability suitable for usual reinforced construction. For less workable concrete such as required for concrete pavement construction, they may be increased about 10 percent. When placement is to be by pump, they should be decreased about 10 percent.

117.349

The water requirement is estimated at about 34 gallons per cubic yard from table 4-4. Since the maximum water-cement ratio is 5.5 gallons per sack, the cement factor must be at least 6.2 sacks per cubic yard. The volume of dry-rodded coarse aggregate is estimated to be 16.9 cubic feet per cubic yard from table 4-9. Thus the weight of coarse aggregate is 16.9 x 104 = 1,758 pounds. The absolute volumes of these quantities of materials is now calculated by use of the relationship:

$$\text{absolute volume} = \frac{\text{weight of material}}{\text{specific gravity x unit weight of water}}$$

The unit weight of water is 62.4 pounds per cubic foot, and water weighs approximately 8.33 pounds per gallon. Thus the absolute volumes are—

Cement

$$\frac{6.2}{3.15} \times \frac{94}{62.4} = 2.97 \text{ cubic feet}$$

Water

$$\frac{34}{1} \times \frac{8.33}{62.4} = 4.54 \text{ cubic feet}$$

Coarse aggregate

$$\frac{1{,}758}{2.61 \times 62.4} = 10.80 \text{ cubic feet}$$

Air

$$\begin{aligned} .06 \times 27 &= \underline{\ 1.62 \text{ cubic feet}\ } \\ \text{Total} &= 19.93 \text{ cubic feet} \end{aligned}$$

The absolute volume of the fine aggregate is—

$$27.00 - 19.93 = 7.07 \text{ cubic feet}$$

and its weight is—

$$7.07 \times 2.66 \times 62.4 = 1{,}170 \text{ pounds.}$$

These estimated quantities should be used for the first trial batch. Subsequent batches should be adjusted by maintaining the water-cement ratio constant and achieving the desired slump and air content.

VARIATION IN MIXES

The proportions arrived at in determining mixes will vary somewhat depending upon which method is used. This occurs because of the nature of these methods. It does not necessarily imply that one method is better than another. Each method begins by assuming certain needs or requirements and then proceeds to determine the other variables. Since the methods begin differently and use different procedures, the final proportions vary slightly. This is to be expected, and it further points out the necessity of trial mixes in determining the final mix proportions.

MIX ADJUSTMENTS

Construction crews in the field convert the designed trial mix proportions into field mix proportions suitable for the mixing equipment available. It must be remembered, however, that the trial mix was designed under controlled conditions based on certain assumptions that may not exist in the field. For this reason, it often becomes necessary for the field crews to adjust the mix for moisture and entrained air.

Moisture

Let's suppose that for a certain structure a trial batch contains basic mix proportions of 5.5 gals of water, 94 lbs of cement, 188 lbs of fine aggregate, and 316 lbs of coarse aggregate.

Now, these proportions are based on the assumption of SATURATED SURFACE-DRY condition of the aggregate–meaning that the aggregate is assumed to contain all the water it is capable of absorbing, but no so-called FREE water over and above that. Aggregate in this condition will use all of the water added at the mixer for cement hydration; that is, the water-cement ratio attained will be that desired by the designers. However, if the moisture content were less than that required for saturated surface-dry condition, then some of the water added at the mixer would be absorbed by the aggregate; in which case, of course, the water-cement ratio would be lower than the design ratio. If, on the other hand, free water existed in the aggregate, then the water-cement ratio, after the addition of the specified amount of water at the mixer, would be higher than the design ratio. Assuming the design ratio to be the optimum required for the highest strength consistent with workability, in either case the quality of the concrete would be less than it should be.

Specification 13Yh requires that accurate procedures be established for determining the quantities of free moisture in the aggregate. The moisture content of aggregate–especially of fine aggregate–is seldom, if ever, less than that required for saturated surface-dry condition. However, aggregate practically always contains some free water over and above that required for saturated surface-dry condition. If the amount of this free water is significant, then it must be taken into account. For example: suppose that the basic mix formula calls for 5.5 gals of water and 188 lbs of sand, and that the available sand already contains 4 percent of free water by weight. This means that to get 188 lb of sand you must weigh out 188 lb + (0.4 x 188 lb), or 188 + 7.52, or 195.52 lb. In this 195.52 lb of sand there exists (0.04 x 195.52), or 7.82 lb of free water. There are 8.34 lb of water in a gallon; therefore, the sand contains 7.87/8.34, or 0.94 gal of free water. Therefore, instead of the basic mix quantity of 5.5 gals, there would be (5.5 - 0.94), or 4.56 gals added at the mixer.

Entrained Air

Air-entrained concrete is a comparatively recent development used to reduce scaling, particularly in areas where concrete must be resistant to severe frost action and impervious to the harmful effects of chemicals used for melting snow and ice. Air-entrained concrete is more durable than normal portland cement concrete, but strength is slightly reduced. The air-entrained mix has increased workability and less segregation, but control is more critical.

Air-entrained concrete consists of cement, fine aggregate, course aggregate, and an admixture such as neutralized vinsoll resin (NVR solution). The addition of such admixtures produces millions of tiny air bubbles–ranging from a few microns to 75 microns in diameter–which are entrained or diffused, in the cement paste. Calculations indicate that there are approximately 600 billion air bubbles entrained in a cubic yard of concrete. Specified percentage by volume usually requires 4-1/2 percent entrained air, with an acceptable range of 3 to 7 percent. Although normal portland cement concrete usually contains from 1/2 to 1-1/2 percent of air, this air is usually entrapped in the form of voids and it is not dispersed uniformly throughout the mix.

The recommended method of producing air-entrained concrete is to add the air-entraining agent to the mixing water at the mixer. The use of commercially prepared air-entrained cement is not recommended because the air-entraining agent may lose effectiveness when it is premixed. Air-entraining agents usually are used with Types I, II, III, IV, and V portland cement in quantities specified by the manufacturer. Air content of the mix must be accurately controlled to obtain the desired uniformity.

The amount of air-entraining agent required to produce any give air content increases with an increase in concrete temperature. Therefore, frequent tests should be made of air contents, particularly if there are changes in the concrete temperatures.

To ensure proper air content, the concrete should be mixed for about 1 or 2 minutes. Air content increases about 1 percent as the mixing time is increased from 1 to 5 minutes. From 5 to 10 minutes, air content remains unchanged. Beyond 10 minutes, it gradually decreases until after 60 minutes the air content is identical to the 1-minute mixing period. The vibration of air-entrained concrete for 1 minute or more in the same spot reduces air content 15 to 20 percent. Internal vibration reduces air content more than external vibration.

The three methods of measuring air content of freshly mixed concrete are the pressure method, the gravimetric method, and the volumetric method. The method most widely used is the pressure method. The principle of the pressure method is based on Boyle's Law; that is, the volume of gas at a given temperature is inversely proportional to the pressure to which it is subjected. An air meter is calibrated so that the percentage of entrained air is read when a known volume of concrete is subjected to a known pressure.

The strength of air-entrained concrete is inversely proportional to a percentage of entrained air. For a given water-cement ratio, strength is reduced about 5 percent for 1 percent of entrained air. Rich mixes are reduced in strength slightly more than lean ones. For pavements, the mix must be adjusted for strength as shown in the following example.

EXAMPLE: Adjust the mix for 4-1/2 percent of air, assuming a trial mix of 1 sack of cement, 195 lbs of sand, 350 lbs of gravel, and 5-1/2 gallons of water.

PROCEDURE: For a 1-sack batch, decrease the amount of water 1/4 gallon per percent of air and decrease the amount of sand 10 pounds per percent of air. (Air bubbles will make the mix appear oversanded unless the amount of sand is reduced.)

SOLUTION:

Trial mix	Correction	Adjusted mix
Cement 1 sack	---	1 sack
Sand 195 pounds	10 x 4-1/2 = 45	150 pounds
Gravel 350 pounds	---	350 pounds
Water 5-1/2 gallons	1/4 x 4-1/2 = 1-1/8	4-3/8 gal
Air	---	4-1/2 percent

To adjust the yield to include the entrained air, the yield as determined from the absolute volumes of the adjusted mix is divided by one minus the percent of air (percentage expressed as a decimal).

$$\text{Yield adjusted for air entrainment} = \frac{\text{Yield (sum of the adjusted solid volumes)}}{1 - \text{\% of air (\% expressed as a decimal)}}$$

ADMIXTURES

Admixtures include all materials other than portland cement, water, and aggregates that are added to concrete, mortar, or grout immediately before or during mixing. Admixtures are sometimes used in concrete mixtures to improve certain qualities such as workability, strength, durability, water-tightness, and wear resistance. They may also be added to reduce segregation, reduce heat of hydration, entrain air, and accelerate or retard setting and hardening. The same results can often be obtained by changing the mix proportions or by selecting other suitable materials without resorting to the use of admixtures (except air-entraining admixtures when necessary). Whenever possible, comparison should be made between these alternatives to determine which is more economical and/or convenient. Any admixture to be in concrete should be added in accordance with current specifications and under the direction of the engineer in charge.

Air Entraining Agents

The most commonly used admixture in concrete mixtures is an air-entraining agent of the type discussed in the previous section on mix adjustments for entrained air. In general, air-entraining agents are derivatives of natural wood resins, animal or vegetable fats or oils, alkali salts of sulfated or sulfonated organic compounds and water-soluble soaps. Most air-entraining agents are in liquid form for use in the mix water. Instructions for the use of the various agents to produce a specified air content are provided by the manufacturer. Automatic dispensers made available by some manufacturers permit more accurate control of the quantities of air-entraining agents used in the mix. The principal reason for using intentionally entrained air is to improve concrete's resistance to freezing and thawing exposure. However, there are other important beneficial effects in both freshly mixed and hardened concrete which include workability, resistance to de-icers, sulfate resistance, strength, abrasion resistance, and watertightness.

FREEZE-THAW RESISTANCE.–The freeze-thaw resistance of hardened concrete is significantly improved by the use of intentionally entrained air. As the water in concrete freezes, it expands, causing pressure that can rupture concrete. The entrained air voids act as reservoirs for excess water forced into them, thus relieving pressure and preventing damage to the concrete.

WORKABILITY.–Entrained air improves the workability of concrete. It is particularly effective in lean mixes and in mixes with angular and poorly graded aggregates. This improved workability allows a significant reduction in water and sand content. The disconnected air voids also reduce segregation and bleeding of plastic concrete.

RESISTANCE TO DE-ICERS.–Entrained air is effective for preventing scaling caused by de-icing chemicals used for snow and ice removal. The use of air-entrained concrete is recommended for all concrete that comes in any contact with de-icing chemicals.

SULFATE RESISTANCE.–The use of entrained air improves the sulfate resistance of concrete as shown in figure 4-15. Concrete made with a low water cement ratio, entrained air, and cement having a low tricalcium aluminate content, such as Type II or Type V portland cement, will be most resistant to attack from sulfate soil waters or seawater. Figure 4-16

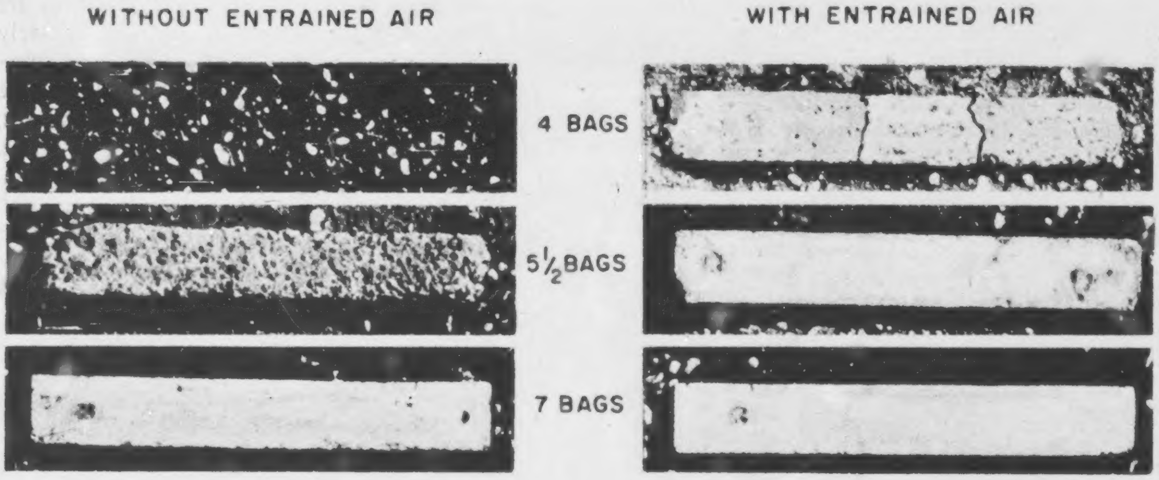

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Figure 4-15. –Effect of entrained air on performance of concrete specimens after 5 years of exposure to a sulfate soil.

117.351
Figure 4-16. —Damage from use of high early strength cement.

illustrates the effects of seawater on concrete made with high early strength cement.

STRENGTH.—Strength of air-entrained concrete depends principally upon the voids-cement ratio. For this ratio, "voids" is defined as the total volume of water plus air (entrained and entrapped). For a constant air content, strength varies inversely with the water-cement ratio. As air content is increased, a given strength generally may be maintained by holding to a constant voids-cement ratio by reducing the amount of mixing water, increasing the amount of cement, or both. Some reduction in strength may accompany air entrainment, but this is often minimized since air-entrained concretes have lower water-cement ratios than non-air-entrained concretes having the same slump. In some cases, however, it may be difficult to attain high strength with air-entrained concrete. Examples are when slumps are maintained constant as concrete temperatures rise and when certain aggregates are used.

ABRASION RESISTANCE.—Abrasion resistance of air-entrained concrete is about the same as that of non-air-entrained concrete of the same compressive strength. Abrasion resistance increases as the compresssive strength increases.

WATERTIGHTNESS.- Air-entrained concrete is more watertight than non-air-entrained concrete, since entrained air inhibits the formation of inter-connected capillary channels. Air-entrained concrete should be used where watertightness is desired.

Water-Reducing Admixtures

Water reducing admixtures are added to concrete mixes to reduce the quantity of mixing water required to produce concrete of a given consistency. Three types are currently available: types A, D, and E as designated in the specifications for chemical admixtures for concrete, ASTM C494.

TYPE A admixtures are used to reduce the quantity of mixing water required to produce concrete of a given consistency.

TYPE D admixtures are water-reducing and retarding admixtures that not only reduce the amount of water required but also retard the setting of concrete.

TYPE E admixtures are water-reducing and accelerating admixtures that not only reduce the amount of water required, but also accelerate the setting and early strength development of concrete.

Retarding Admixtures

Retarders are sometimes used in concrete to reduce the rate by hydration to permit the placement and consolidation of concrete before the initial set. These admixtures are also used to offset the accelerating effect of hot weather on the setting of concrete. These admixtures, classed as Type B, generally fall into the categories of fatty acids, sugars, and starches.

Accelerating Admixtures

Accelerating admixtures, (ASTM Type C) accelerate the setting and the strength development of concrete. Calcium chloride is the most commonly used accelerator. It should be added in solution form as part of the mixing water and should not exceed 2 percent by weight of cement. Calcium chloride or other admixtures containing soluble chlorides should not be used in prestressed concrete, concrete containing embedded aluminum, concrete in permanent contact with galvanized steel, or concrete subjected to alkali-aggregate reaction or exposed to soils or water containing sulfates.

SLUMP TEST

The slump test is used to measure the consistency of the concrete. The test is made by using a SLUMP CONE; the cone is made of No. 16 gage galvanized metal with the base 8 inches in diameter, the top 4 inches in diameter, and the height 12 inches. The base and the top are open and parallel to each other and at right angles to the axis of the cone. A tamping rod 5/8 inch in diameter and 24 inches long is also needed. The tamping rod should be smooth and bullet pointed (not a piece of rebar).

Samples of concrete for test specimens should be taken at the mixer or, in the case of ready-mixed concrete, from the transportation vehicle during discharge. The sample of concrete from which test specimens are made will be representative of the entire batch. Such samples should be obtained by repeatedly passing a scoop or pail through the discharging stream of concrete, starting the sampling operation at the beginning of discharge, and repeating the operation until the entire batch is discharged. The sample being obtained should be transported to the testing site. To counteract segregation, the concrete should be mixed with a shovel until the concrete is uniform in appearance. The location in the work of the batch of concrete being sampled should be noted for future reference. In the case of paving concrete, samples may be taken from the batch immediately after depositing on the subgrade. At least five samples should be taken from different portions of the pile and these samples should be thoroughly mixed to form the test specimen.

The cone should be dampened and placed on a flat, moist nonabsorbent surface. From the sample of concrete obtained, the cone should immediately be filled in three layers, each approximately one-third the volume of the cone. In placing each scoopful of concrete the scoop should be moved around the top edge of the cone as the concrete slides from it, in order to ensure symmetrical distribution of concrete within the cone. Each layer should be RODDED IN with 25 strokes. The strokes should be distributed uniformly over the cross section of the cone and should penetrate into the underlying layer. The bottom layer should be rodded throughout its depth.

When the cone has been filed to a little more than full, strike off the excess concrete, flush with the top, with a straightedge. The cone should be immediately removed from the concrete by raising it carefully in a vertical direction. The slump should then be measured to the center of the slump immediately by determining the difference between the height of the cone and the height at the vertical axis of the specimen as shown in figure 4-17.

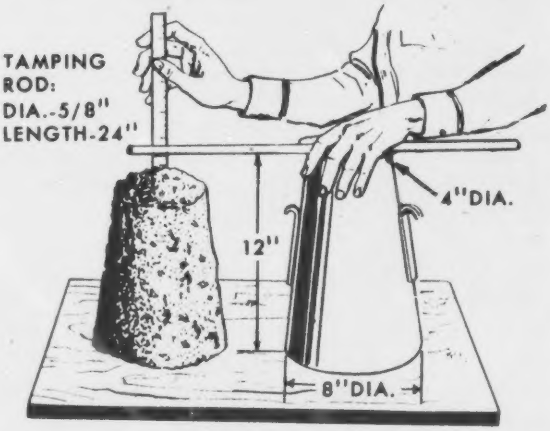

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Figure 4-17. —Measurement of slumps.

The consistency should be recorded in terms of inches of subsidence of the specimen during the test, which is called slump.. Slump equals 12 inches of height after subsidence.

After the slump measurement is completed, the side of the mix should be tapped gently with the tamping rod. The behavior of the concrete under this treatment is a valuable indication of the cohesiveness, workability, and placeability of the mix. A well-proportioned workable mix will gradually slump to lower elevations and retain its original identity, while a poor mix will crumble, segregate, and fall apart.

MAKING SAMPLES FOR LAB TESTS

You may be called upon to mold cylinders and beams for compression and flexural tests to be run later in the lab.

The first step is to obtain a sample of the concrete. The sample should consist of not less than 1 cu ft when it is to be used for strength tests. Smaller samples may be permitted for routine air content and slump tests.

The procedures used in sampling should include the use of every precaution that will assist in obtaining samples that will be representative of the true nature and condition of the concrete sampled, as follows:

1. *Sampling from Stationary Mixers, Except Paving Mixers.*—The sample must be obtained by passing a receptacle completely through the discharge stream of the mixer at about the middle of the batch, or by diverting the stream completely so that it discharges into a container. Care must be taken not to restrict the flow from the mixer in such a manner as to cause the concrete to segregate. These requirements apply to both tilting and nontilting mixers.
2. *Sampling from Paving Mixers.*—The contents of the paving mixer must be discharged, and the sample must be collected from at least five different portions of the pile.
3. *Sampling from Revolving Drum Truck Mixers or Agitators.*—The sample must be taken at three or more regular intervals throughout the discharge of the entire batch, except that samples must not be taken at the beginning or end of discharge. Sampling must be done by repeatedly passing a receptacle through the entire discharge stream, or by diverting the stream completely so that it discharges into a container. The rate of discharge of the batch must be regulated by the rate of revolution of the drum, and not by the size of the gate opening.

The sample must be transported to the place where test specimens are to be molded or where the test is to be made, and must be remixed with a shovel the minimum amount to ensure uniformity. The sample must be protected from sunlight and wind during the period between taking and using, which must not exceed 15 minutes.

Cylinders for Compressive Strength Tests

The compressive strength of concrete (that is, the ability to resist a CRUSHING force) is, as previously explained, controlled by the W-C. However, the theoretical compressive strength related to a particular W-C will be attained only if the actual amount of water added is carefully regulated in accordance with the considerations previously mentioned. To determine what compressive strength was actually attained, samples cast from the mix being used must be cured and tested.

Tests are made on 6 in. by 12 in. cylinders, cast in cylindrical molds. For the final test, a cylinder is cured for 28 days; however, the PROBABLE 28-day strength a mix will attain can be estimated by determining the 7-day strength (which usually runs about 2/3 of the 28-day strength). Therefore, one or more cylinders are tested after 7 days of curing.

Test cylinders are cast in either metal or heavy cardboard molds. For filling, a mold is placed on a metal BASE PLATE. To avoid loss of mix water, the bottom of the mold is sealed to the base plate with paraffin. A cardboard mold is expendable—that is, for stripping it is simply torn off. A metal mold is hinged, so that it can be stripped by opening. Before filling, the inside surface of the mold and base plate are lightly oiled, to prevent the concrete from BONDING (adhering) to the mold and plate.

The test specimens shall be formed by placing the concrete in the mold in three layers of approximately equal volume. In placing each scoopful of concrete, the scoop must be moved around the top edge of the mold as the concrete slides from it in order to ensure a symmetrical distribution of the concrete within the mold. The concrete must be further distributed by a circular motion of the tamping rod. Each layer must be rodded with 25 strokes of a 5/8 in. round rod, approximately 24 in. in length and tapered for a distance of 1 in. to a spherically shaped end having a radium of approximately 1/4 in. The stokes must be distributed uniformly over the cross-section of the mold and must penetrate into the underlying layer. The bottom layer must be rodded throughout its depth. Where voids are left by the tamping rod, the sides of the mold must be tapped to close the voids. After the top layer has been rodded, the surface of the concrete must be struck off with a trowel and covered with a glass or metal plate to prevent evaporation.

After about 24 hours of hardening, the mold is stripped off and the cylinder is immersed in water, moist sand, moist sawdust, or moist earth for curing. At the expiration of the curing period (7 or 28 days), the cylinder is CAPPED on both ends, with a thin layer of gypsum CASTING PLASTER or sulfur CAPPING COMPOUND. For testing, the cylinder is placed under the piston of a machine capable of applying a very high pressure (for a 6 in. diameter cylinder with a compressive strength of about 6000 psi, the rupturing pressure must reach about 170,000 lbs). Pressure is applied, and increased until the cylinder collapses.

Beams for Flexural Strength Tests

The compressive strength of concrete is its ability to resist a crushing force; the FLEXURAL strength is ability to resist a BREAKING force. The flexural strength of concrete is considerably less than its compressive strength.

For a flexural strength test a TEST BEAM, cast in a TEST BEAM MOLD like the one shown in figure 4-18, is cured and then broken by a BEAM BREAKER.

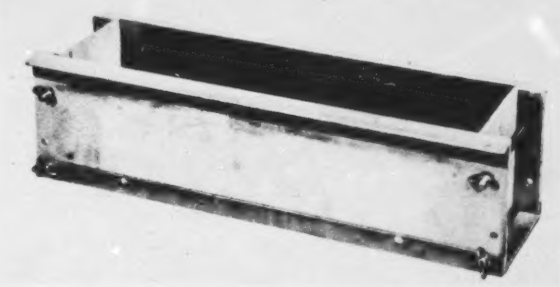

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Figure 4-18. —Test beam mold.

The test specimen must be formed with its long axis horizontal. The concrete must be placed in layers approximately 3 in. in depth and each layer must be rodded 50 times for each square foot of area. The top layer must slightly overfill the mold. After each layer is rodded, the concrete must be spaded along the sides and ends with a mason's trowel or other suitable tool. When the rodding and spading operations are completed, the top must be struck off with a straightedge and finished with a wood float. The test specimen must be made promptly and without interruption. Test beams should be cured for a period of 28 days. Like cylinders, the flexural strength may be determined after 7 days utilizing the probable 28 day strength of concrete.

CONCRETE EQUIPMENT

Concrete equipment includes such items as concrete block manufacturing plants, conventional form riding pavement equipment, and the slip form paver. As a Builder 1 or C, you are not required to operate this equipment but in order to supervise concrete construction operations involving their use, you must be familiar with their general operating principles and applicable safety precautions.

CONCRETE BLOCK MANUFACTURING EQUIPMENT AND PROCEDURES

Concrete block can be made by casting an ordinary plastic type of mix in forms. In this case, however, the forms cannot be stripped until after the interval required for ordinary plastic concrete. Most concrete blocks are made in machines which permit immediate removal of the form from a green block. A block machine molds a unit by vibrating, by the application of pressure (tamping), or by a combination of both methods. In recent years, vibration has come to occupy an increasingly important position in the industry, and many of the high-capacity machines now on the market apply vibration in some manner to the mold box. Vibration improves density, strength, and surface texture.

For a particular machine, the manufacturer's manual is the only satisfactory guide to the procedure for operating and caring for the machine. Figures 4-19 and 4-20 show the block-molding parts of a typical machine. Here mix is fed into the mold from an overhead hopper, after which a tamper strikes the mix a heavy blow. The mold is then raised clear of the green block (clear of more than one green block in a machine which molds more than one at a time). The pallet on which the block(s) rest is then fed out onto a table, while another pallet is fed under the hopper. Pallets containing green blocks are stacked on a portable rack. When the rack is filled, it is moved to the curing area.

Block Plant Layout

The plant floor level should be not less than 6 in. above the general grade of the yard, to assure adequate drainage. In addition, concrete yard runways should be slightly above the grade of the surrounding yard, so that they will remain free of pebbles and other obstructions which might interfere with the operation of lift trucks and other equipment.

Adequate space should be allowed at the sides and in front of the block machine, so that lift trucks can be maneuvered with the maximum speed and ease. The general tendency in the layout of plants has been to economize on space in the immediate area of the block machine, on the theory that compactness produces efficiency. Though this theory is generally true when hand-lift trucks are used, the advantage disappears when power lift trucks are utilized. It

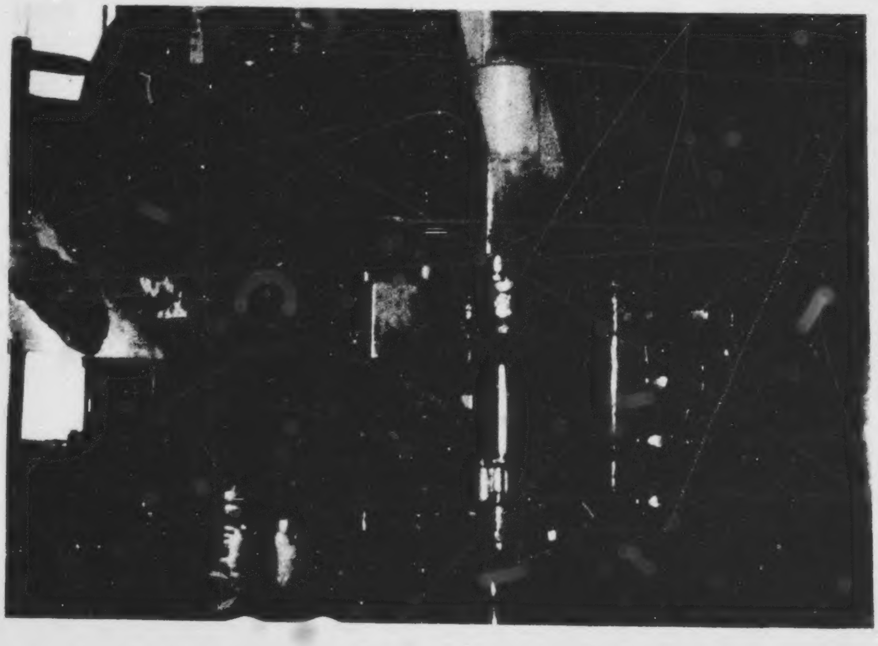

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Figure 4-19. —Concrete block machine, showing block directly below elevated form.

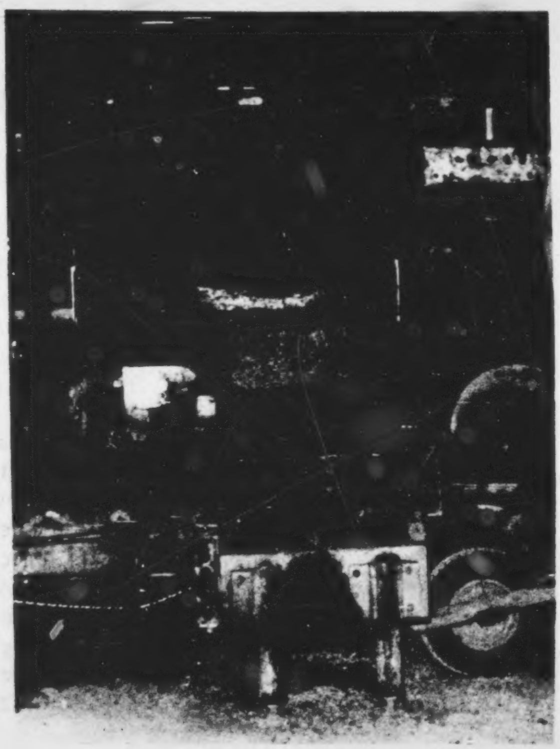

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Figure 4-20. –Concrete block machine, showing finished block emerging.

is therefore well to err on the side of too much space adjacent to the machine. However, regardless of the general layout, aggregate and cement should be stored as near the mixer as possible.

The trend is toward the practice of elevating all raw materials into overhead bins, for gravity discharge from the mixer into the machine. For obvious reasons, if the raw materials are elevated at all, the elevation should be high enough to permit gravity flow. With such an arrangement the mixer is located on a separate floor level directly above the block machine.

Concrete Block Mix Design

Machine-made blocks must, if the forms are to be stripped at once for re-use, be made with a mix which is dry, or nearly dry, (that is, has a zero slump or less) at the time the forms are stripped. For a load-bearing concrete building unit the compressive strength requirement seldom exceeds 800 psi. For a compressive strength of only 800 psi, you could in theory use 20 gals of water per sack of cement. Obviously this would produce an extremely soupy mix which could never be used machinewise. Therefore, the conclusion is that any quantity of water you use per sack that will get a mix of reasonable consistency will be well within the maximum quantity prescribed for the desired compressive strength. This means that the W-C ratio, which is usually the basic factor in the design of an ordinary concrete mix, is more or less irrelevant in the design of a block mix. For a block mix, the ratio of cement to fine aggregate to coarse aggregate is the controlling factor. The water you add is enough water to ensure that (1) all aggregate particles are mortared, and (2) the mix will have a consistency which suits the particular machine. In practice this works out usually to a W-C ratio of about 5:1.

A typical block mix formula is 1 cement: 5.3 sand: 2.7 coarse, by volume. Because lightweight aggregate is often used in block, mix formulas are often given by volume rather than by weight.

The first thing to note about the given typical formula is that it follows a general rule to the effect that, in a block mix, the ratio of fine aggregate to coarse is about 2:1. This is roughly the reverse of the usual ratio of fine to coarse for an ordinary mix, indicating that here again the high ratio of fine to coarse is the chief factor in producing a "dry" mix.

These proportions presume a mix in which all the fine aggregate will pass the No. 4 sieve, and in which the maximum size of coarse is 3/8 in. In general, 3/8 in. is the largest coarse which can be used in hollow units.

The general rule of a ratio of 2 fine to 1 coarse is only a general starting point. The same applies to a second rough rule, to wit: that the proportion of cement to total amount of aggregate is about 1:8 by volume. Satisfactory proportions can be determined only by trial mix and test, the object being to determine the mix which will produce the maximum strength for a given expenditure of cement. Trial mixes containing fine to coarse ratios of 4:1 (25% coarse), 3:1 (33-1/3% coarse), 2.2:1 (45% coarse), and

1.8:1 (55% coarse) should be tried with ratios of cement to total aggregate of 1:6, 1:7, 1:8, 1:9, 1:10 and 1:11. All these proportions are by damp, loose volume.

In general, the coarser the grading of the aggregate, the greater the strength of the unit will be for a given cement content. However, the coarseness of the mix is limited by the extent to which fines are required for machine workability. It is at the machine itself that the first indication of suitable aggregate and cement combination becomes apparent. If the appearance of the surface and edges of a test block is satisfactory and if the units being produced can be handled easily without broken webs and corners, the mixture is approaching suitability.

Uniform grading (similar to that prescribed for ordinary concrete) is usually best for block. When units in trial batches break easily, the trouble is usually the fact that the fine aggregate is deficient in fines. A sieve analysis is then in order. If a deficiency of fines appears, the addition of small amounts of fine sandstone screening or other fine aggregate will aid in making the mix more workable (remember that here again workability means adaptability to machine-tamping or packing).

Mixing For Block

As mentioned before, you can't in the nature of things add enough water to a block mix to weaken the concrete. The usual tendency has been to err on the opposite side, by not using enough water. Water should be added to the point where a freshly stripped unit will just stand up, with the surface showing occasional web-like water marks.

Experienced operators are usually able to test the mixture for water content by squeezing a handful of it. When traces of moisture show on the outside of a squeezed handful, the water content is usually about right.

The relatively dry mix used in a block machine requires longer mixing time than that required for an ordinary mix. The time must be long enough to ensure that every aggregate particle in the mix is mortared, and a high preponderance of fine creates a much larger particle surface area than is the case with an ordinary mix of the same volume.

There is difference of opinion as to just what mixing time is necessary to achieve thorough coating of the particles. Some producers mix their materials for as long as 15 or 20 minutes, which requires, of course, additional expense for mixing capacity. More conservative authorities believe that mixing time beyond about 6 minutes is not economically justified.

For a mix using ordinary dense aggregate (sand and gravel), the cement and aggregate should be mixed dry for about a minute before the water is added. With lightweight aggregate, the aggregate and about one-half to two-thirds of the water should be mixed together for 2 or 3 minutes before the cement is added. This practice is necessitated by the highly absorbent character of lightweight aggregate. Premixing as described fills the pores of the aggregate with water before the cement is added, thus preventing dry cement from getting into the pores where it would be ineffective. After the remainder of the water has been added, at least 6 minutes mixing time should be allowed.

Quantity Estimating

You know how to determine the yield of concrete per every 1-sack batch of a given mix. Suppose that for your block mix this works out to 4.2 cu ft of concrete per 1-sack batch. How many 1-sack batches would you need to make, say, 800 units of the type shown in figure 4-21? This depends on the volume of concrete in each unit. For the unit shown in figure 4-21, the face shells and webs are 1 inch thick. The volume of concrete in each face shell is therefore 15-5/8 x 7-5/8 x 1, or 119 cu in. Therefore, the volume of concrete in the face shells is 2 x 119, or 238 cu in. The volume of concrete in each web is (8 - 2) x 7-5/8 x 1, or 45.7 cu in. The volume of concrete in the four webs is therefore 4 x 45.7, or 182.8 cu. in. The total volume of concrete in the unit is 238 + 182.8, or 420.8 cu in. There are 1728 cu in. in a cu ft; therefore, the number of cu ft of concrete in each unit is 420.8/1728, or 0.244 cu ft. For 800 units, then, you will need 800 x 0.244, or 195.2 cu ft. If you get 4.2 cu ft from each 1-sack batch, the

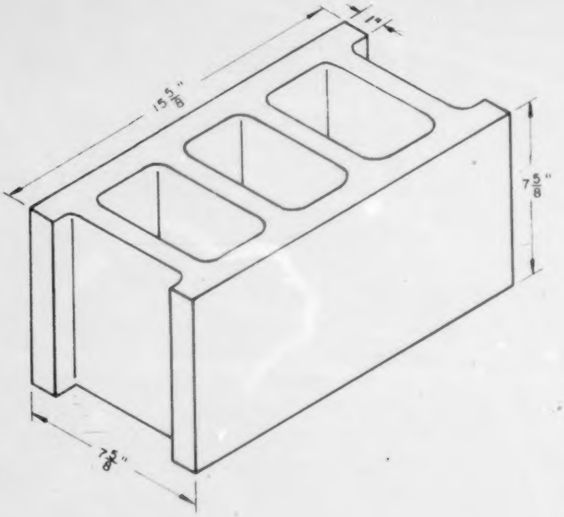

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Figure 4-21. —One type of concrete block.

number of 1-sack batches you will need for 195.2 cu ft is 195.2/4.2, or about 46. Therefore, you will need 46 sacks of cement. From the number of sacks of cement and the mix formula, you can determine the quantities of fine and coarse aggregate you will need.

Curing Concrete Block

Much breakage of concrete block during shipment and handling, and much inadequate service of block in walls and other structures, are results of inadequate or improper curing. In a warm climate in which the temperature will not drop below about 60°F, blocks can be satisfactorily cured in the yard, provided that adequate cover (as of straw, tarpaulin, etc.) is used for each block to prevent evaporation of surface moisture. Yard-curing is usually impractical, however, because of the difficulty of providing adequate cover for large numbers of units, and because yard-curing requires a full 28-day interval. Consequently, block is usually cured in a specially constructed curing room, in which both the prevention of moisture evaporation and the maintenance of satisfactory temperature are provided by the introduction of steam.

CONSTRUCTION OF THE CURING ROOM.—A curing room should be sufficiently tight to prevent excessive rapid heat loss, and the door enclosures should fit as tightly as possible for the same reason. These enclosures may consist of hinged or vertical-sliding counterweighted doors, but canvas drop curtains are often used on curing-room doors which connect with the block-machine room. The ideal arrangement is one in which the curing room has no openings to the outside, but only openings to the block-machine room.

Side walls and partitions are usually built of 8 x 8 x 16 concrete masonry units. Light-weight units usually provide better heat insulation than units containing ordinary dense aggregate. The roof should consist of poured concrete slab, additionally insulated. A room is generally made wide enough to hold two racks side by side, with about 12 in. clearance between them, and overhead clearance of at least 12 in., more, of course, if lift trucks are to be used for stacking pallets. However, the ceiling should be as low as possible to keep the heat as low as possible, since there may be a temperature differential between floor and ceiling of as much as 50°.

The ceiling should be crowned or pitched, so that moisture from condensation will tend to run down to the side walls, rather than drip on the loaded racks. Inside wall surfaces and ceiling surface should be given a sealed coating if possible.

LOW-PRESSURE STEAM CURING.—Most concrete block is cured at relatively low temperature (120°F or less) with low-pressure steam. There are various methods for introducing steam into the curing room and maintaining desirable temperature and humidity. Dry heat may be provided by 2-in. diameter RADIATION COILS extending the full length of the room on both sides. Or fog-heat may be provided by adding fog nozzles (attached to the ceiling) to the radiation coils. In still another system, steam, moisture, and radiation are combined by opening petcocks in the bottom return line of the radiation coil.

HIGH-TEMPERATURE STEAM CURING.—Block can be steam-cured at 120°F in about 48 hours. HIGH-TEMPERATURE-STEAM curing reduces this interval to about 24 hours. The block is first moist-cured for about 12 hours, then dry-cured in an ordinary low-pressure room at a temperature of about 200°F. A circulating hot-air furnace is required to attain the required temperature, and the room should be arranged (by the installation of exhaust fans) so that moisture from the wet cycle can be quickly exhausted in preparation for the dry cycle.

HIGH-PRESSURE-STEAM CURING.–Curing in as little as 9 or 10 hours can be accomplished by the use of high-pressure steam. Cylindrical steel AUTOCLAVES (steam-tight cylinders) are used for the purpose. The freshly made units are wheeled into the cylinders, the closures are made, and steam at 120 psi is introduced. Inside temperature rises to about 350° in about 3 hours. After 7 or 8 hours of curing the steam is turned off. It takes about 1/2 hour for the pressure inside the autoclave to subside to normal atmospheric pressure; the units are then removed.

CONCRETE PAVING EQUIPMENT

Concrete paving equipment can be broken down into three groups: form riding apparatus, slip-form equipment, and accessory finishing items. Because paving with forms is the most common method used, form riding equipment comprises the bulk of concrete paving devices available in the Navy system. A number of items in the slip-form category have been recently introduced, however. Equipment in the accessory finishing group, such as the concrete saw and the portable curing machine, can be used in paving projects regardless of the paving method.

Form Riding Equipment

When all items of form riding equipment are available and ready for use they comprise the complete form riding paving train which consists of the forms, subgrader, spreader, transverse finisher, longitudinal finisher, finishing bridge, and the automatic curing machine. In some cases all of these items of equipment may not be available, and for this reason the discussion here will deal with the standard items of equipment, those being the forms, spreader, transverse finisher, and the automatic curing machine.

FORMS.–The standard concrete form (figure 4-22) is 10 feet long and varies between 8 and 12 inches in height. Each form has three pin sockets with locking wedges. When pins are driven through the sockets, they provide an anchor to the subgrade and alignment of the forms. The locking wedges clamp the pins to the forms and allow for minor alignment corrections. Each form has a receiving key on one end and a locking plate on the other for connection with other forms. The form can be shimmed up to 25 percent of its original height. However, the shim must be placed under the full width and length of the base.

Paving forms serve two functions: to contain concrete in a specified area and to provide a traction surface for form riding equipment. Forms should be set true to line and grade on a thoroughly compacted subgrade with uniform bearing under their entire length. Since the top of the forms will control the final grade, the forms must be accurately surveyed when being placed. The maximum deviation from a straight line running parallel to the form top is 1/8 inch. The distance between the inside surfaces of opposite forms should not vary more than 1/4 inch.

Whenever a form section becomes damaged so that there is more than a 1/10 inch variation on top of the form, the form must be repaired or replaced. Form oil should be applied to the inside face of all forms to facilitate removal. Under normal conditions, the forms should remain in place for 12 hours before being removed.

CONCRETE SPREADER.–The concrete spreader (fig. 4-23) is a gasoline engine-powered, self-propelled form riding unit designed to spread, strike-off, and vibrate concrete in a single operation. The spreader works intermittent batches of concrete from pavers, mixers, or central plants into a continuous slab of

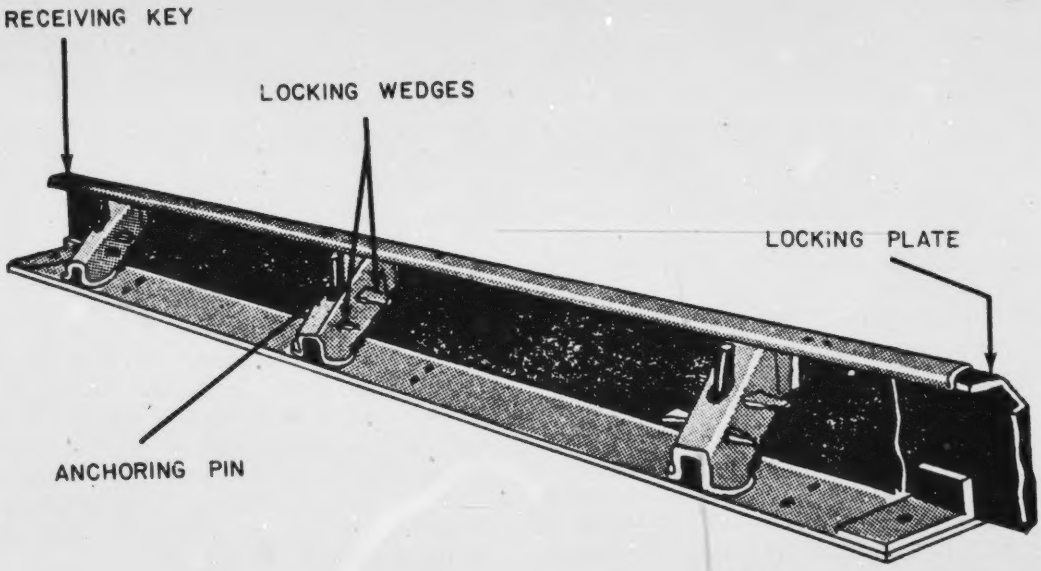

Figure 4-22. –Concrete paving form.

uniform thickness. With this machine it is possible to strike off concrete at a specified level for the installation of reinforcing mesh and then to spread a top layer to the required level. The spreader is adjustable in 6-inch increments over widths ranging from 20 to 25 feet. A speed-change transmission enables the machine to work mixes with slumps preferably varying from 3 to 5 inches.

Spreading.–The wet concrete is spread by a V-type trolley blade that moves transversely between the forms as the spreader travels forward. The trolley blade can be positioned below, above, or even with the top of the paving forms. The blade should be set 1 to 2 inches above the strike-off plate.

Strike-off.–The strike-off plate strikes off the concrete at the desired elevation which can be below, above, or even with the top of the forms. The strike-off plate can be warped to give the pavement a positive crown up to 2-1/2 inches. Although the strike-off height above the forms will vary according to aggregate size and the slump of the mix, the strike-off plate is normally set 1/2 to 3/4 of an inch above final grade to facilitate finishing.

Vibrating.–The struck concrete is then vibrated to consolidate the mix. The spreader is equipped with two types of vibrators, a pan type and an internal "finger type." The pan type is used to vibrate concrete up to, and including, 12 inches thick. The internal "finger type" is used to consolidate concrete thicker than 12 inches. Only one vibrator can be used at one time.

Starting The Lane.–When starting a new paving lane, lay a spur of forms behind the point where placement is to begin. This "shake out" distance ensures that the spreader will be operating properly before it contacts the fresh concrete. If it is not possible to construct the spur, spread and vibrate the first 15 feet of concrete by hand before moving the spreader onto the forms.

Techniques For Maximum Production.–The following list of techniques will help supervisors to achieve maximum output.

Figure 4-23. —Concrete spreader.

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1. Keep the tops of the forms and the spreader wheels clean, dry, and oil-free. This increases traction and permits the spreader to perform efficiently.
2. Do not dump concrete in a pile in front of the spreader; spread while dumping.
3. Adjust the speed of the machine to complement the rate of concrete production. Slow this rate if the spreader becomes overloaded.
4. The concrete spreader can operate on a maximum grade of 8 and 10 percent, but when grades are encountered, stiffen the concrete mix slump and ballast the spreader to increase wheel traction.
5. Adjust the strike-off plate to compensate for the tendency of concrete to work toward the low side of superelevated curves. To correct this, lower the plate on the low side of the curve and lift it on the high side.

TRANSVERSE CONCRETE FINISHER.—The transverse concrete finisher (figure 4-24) is a gasoline-powered, self-propelled form riding unit that follows the spreader and shapes the concrete to the specified cross section. The finisher has two tandem screeds that move transversely across the concrete, with a reciprocating motion. These screeds may be adjusted so that the finished concrete surface can have from zero to a 2-1/2 inch positive crown. The screeds may be tilted so that the leading edge is higher than the trailing edge. The screeds should be tilted when finishing a dry, harsh mix, or a mix with exceptionally coarse aggregates. A tilted screed is less likely to "tear" the surface of the concrete.

When starting the paving job, set both the forward and screed speeds in the lowest range. Advance both speeds and observe the effect on the finished surface. Fast forward speed and

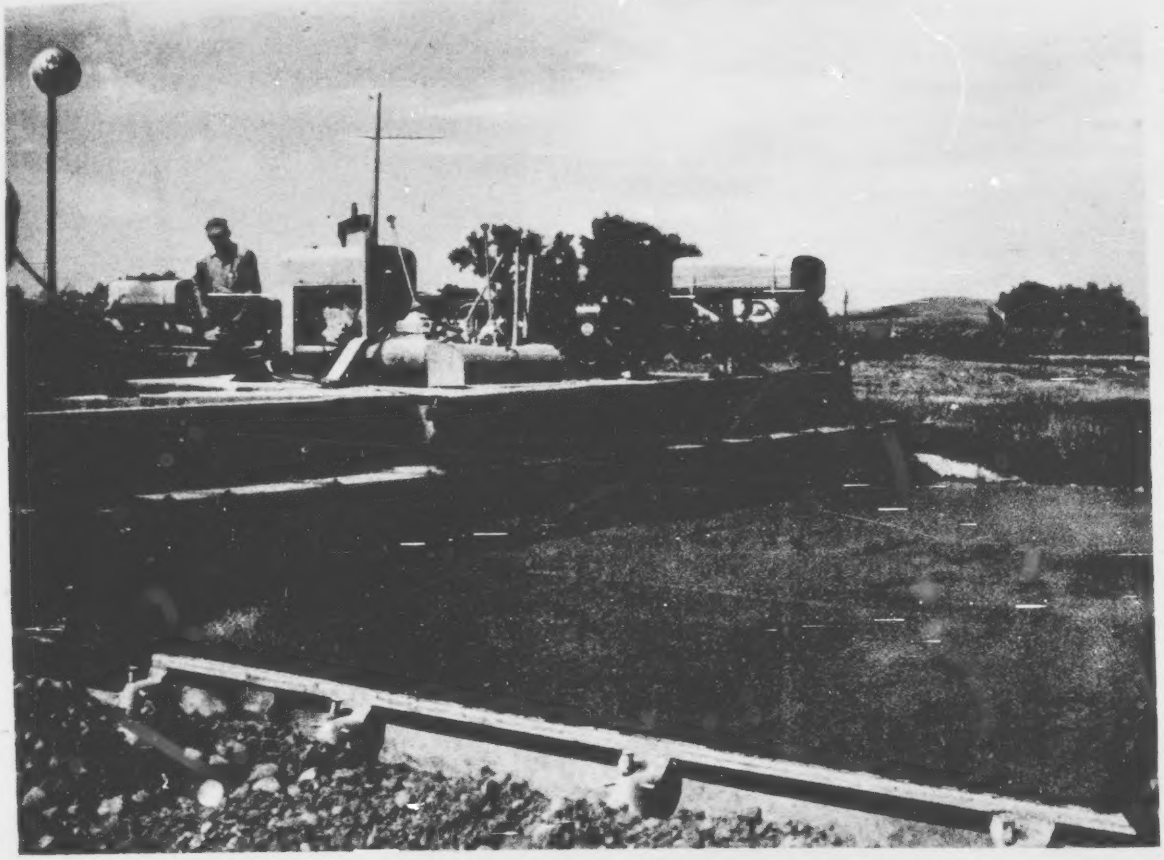

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Figure 4-24. –Transverse concrete finisher.

slow screed can "tear" the concrete; slow forward speed with fast screeds can "overfinish" the surface. For low slump, large aggregate concrete, the screed speed should be increased while the forward movement of the finisher is held constant. Small aggregate, high slump mixes require a slower screed and a faster forward finisher speed.

Screed Surge.–The front or leading screed should carry a 4- to 8-inch surge of concrete in front of it to facilitate proper finishing. If this surge gets large enough to spill over the forms, the strike-off plate on the spreader is too high and should be lowered.

Alternate Vibrator.–Some finishers are equipped with pan-type vibrators mounted between the screeds, which are used only when the concrete has not been vibrated previously. If a concrete spreader is unavailable, the transverse finisher may be used to vibrate and finish the concrete after considerable hand spreading has been done.

AUTOMATIC CURING MACHINE.–Automatic curing machines (figure 4-25) are form riding and self-propelled. Although the machines vary with make and model, each has a telescoping frame that supports a deck. An engine that is mounted on the deck provides power for the traction wheels and a pump. The deck has room for approximately a 1-day supply of curing material in 55-gallon drums. The pump draws this material from the drums and forces it

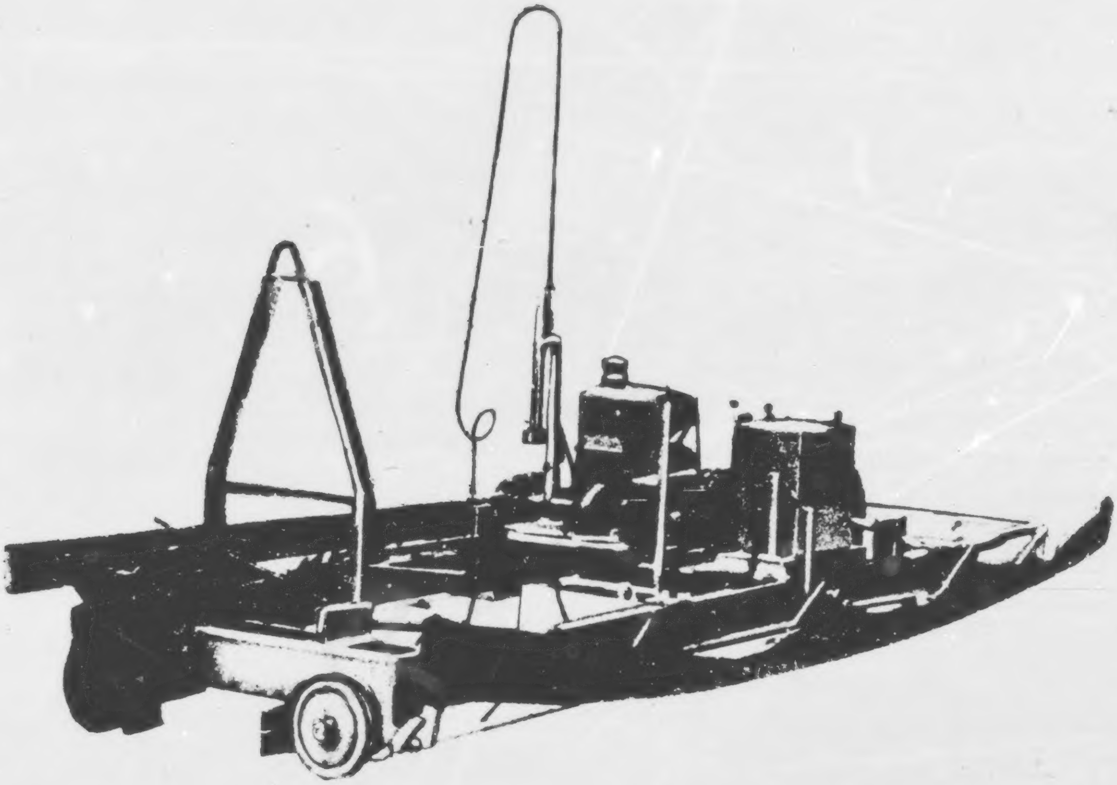

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Figure 4-25. –Automatic curing machine.

out through a spray assembly onto the pavement.

Slip-Form Equipment

A slip-formed pavement, like one laid by the conventional form method, can be little better than the subgrade beneath it. Base preparations for slip-form paving follow the same requirements used in conventional form paving. Accurate form grade operations must be carried out because the form grade serves as the base of operation for the slip form. Also, the level of the form grade controls the riding level and thickness of the pavement to be placed.

SLIP-FORM PAVER.–The slip-form paver (figure 4-26) is a concrete laying machine which dispenses with the need for conventional paving forms or form-riding equipment. In a single pass, this machine spreads, forms, compacts, finishes, and belts the concrete while controlling the width, thickness, alignment, and riding surface of the pavement well within the specified project requirements.

The basic components of the slip-form paver are the spreading screws and strike-off assembly, vibrating beam, tamper bars, extrusion plate, finishing belts, left and right crawler assemblies, power unit (10/kilowatt electric generator driven by a gasoline engine), and operator's deck with control console. The paver's traction power is supplied by two 2-horsepower electric motors

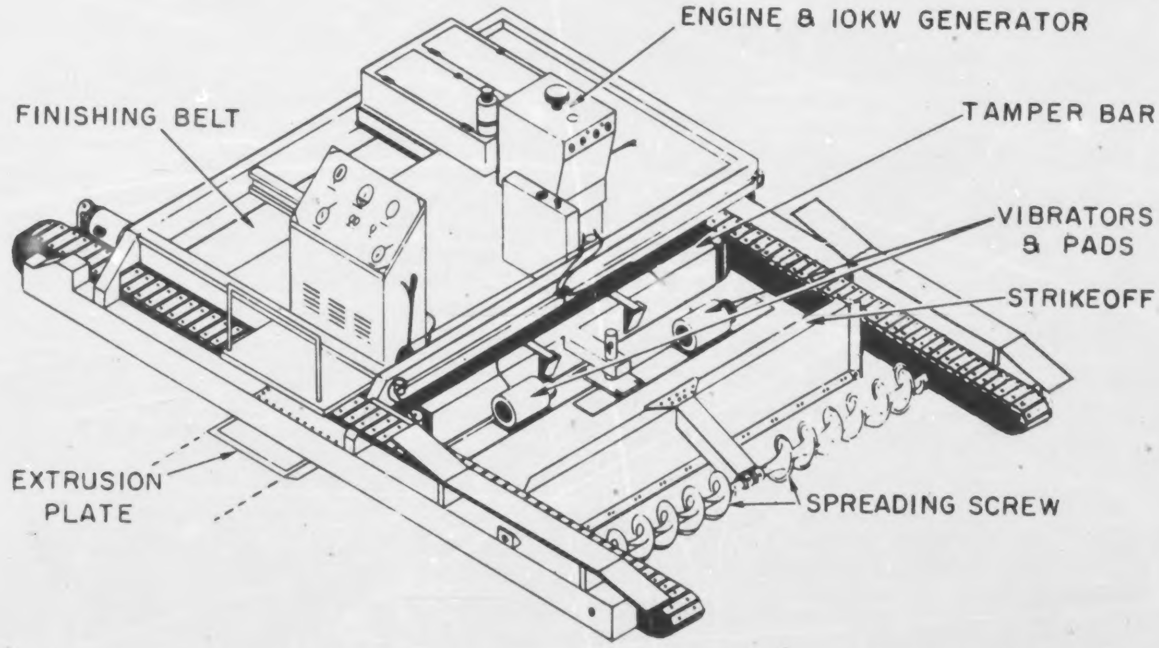


Figure 4-26. –Slip-form paver.

which drive the tracks through a 100 to 1 reduction gear.

The concrete used in slip-form paving operations must have a uniform consistency and be placed upon a well-compacted, accurately graded base to ensure a smooth, uniform concrete slab with excellent riding characteristics. The concrete should have a slump of 1 inch and should not exceed 3 inches.

During actual operation, concrete is evenly spread in front of the strike-off screw and between the slip-forms slightly higher than the desired slab thickness. It is then struck off by the strike-off screw and vibrated with a beam vibrator, and tamped by the tamping bars. As the paver continues forward, the concrete is pressed down and squeezed out behind the extrusion plate under the weight of the machine. This pressure consolidates the concrete and contributes to the high stability and lack of slump when the trailing forms pass on.

Following the extrusion plate, a 24-inch wide finishing belt dresses the surface of the pavement. Finally, as the attached trailing forms are pulled forward, a burlap drag adds texture to the finished surface. The paver controls are located on an operator's console. The production rate of the slip-form paver is normally governed by the amount of concrete placed in front of it (plant output).

PRECAST CONCRETE

Precast concrete is any concrete member that is cast in forms at a place other than its final position of use. The member may be of either plain or reinforced concrete. It can be done anywhere although this procedure is best adapted to a factory or yard. Job-site precasting is not uncommon for large projects. Some manufacturers produce a variety of structural members in several different shapes and sizes, including piles, girders, roof members and other standard products.

Generally, structural members including standard highway girders, piles, electric poles, masts and building members are precast by factory methods unless the difficulty or impracticability of transportation makes job-site casting more desirable. The economies obtained by precasting standard members or members required in large numbers in a central location, for a particular project, are readily apparent.

Economy of mass production is the principal advantage of precasting. Added to this is the desirability of fabricating on the ground rather than in the final position the member is intended for.

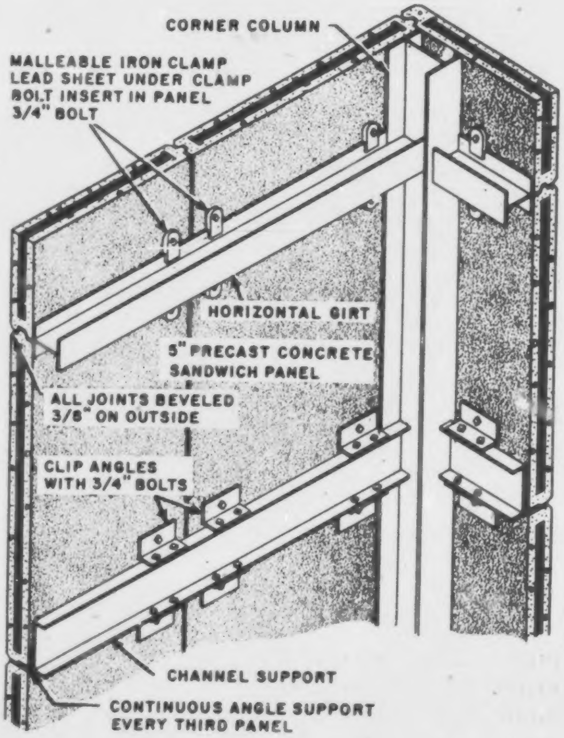
WALL PANELS

Wall construction is frequently done with precast wall PANELS originally case horizontally (sometimes one above the other) as slabs. This method has many advantages over the conventional method of casting in place in vertical wall forms. Since a slab form requires only edge forms and a single surface form, the amount of form work and form materials required is greatly reduced. The labor involved in slab form concrete casting is much less than that involved in filling a high wall form. One side of a precast unit cast as a slab may be finished by hand to any desired quality of finish. The placement of reinforcing steel is much easier in slab forms, and it is easier to attain thorough filling and thorough vibrating. Precasting of wall panels as slabs may be expedited by mass production methods not available when casting in place.

Relatively light panels for nonbearing concrete walls are precast as slabs and attached to a previously erected building frame as shown in figures 4-27 (steel frame) and 4-28 (concrete frame). The panels, after transportation from the casting yard, may be set in place from outside the building by cranes, or they may be set from within by forklift truck or even by block and tackle.

ERECTING PRECAST ELEMENTS

The erection of precast members is similar to steel erection. Cranes or derricks of sufficient capacity are the usual means of lifting the members. Spreader bars frequently must be used in order to handle the elements at the correct pickup points. In some cases, due to long length or heavy weight, two cranes or derricks may be necessary to lift the members.

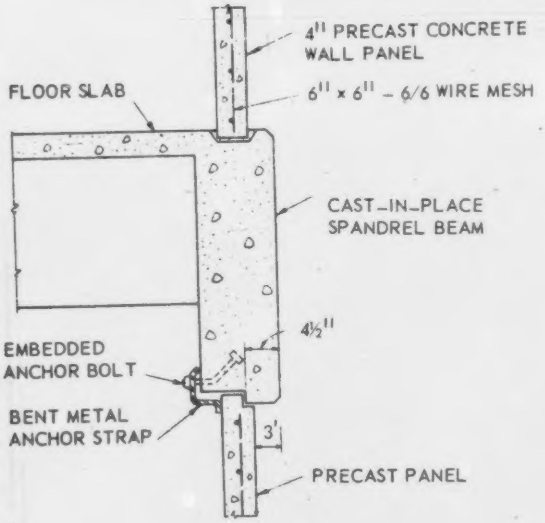

CORNER COLUMN
MALLEABLE IRON CLAMP
LEAD SHEET UNDER CLAMP
BOLT INSERT IN PANEL
3/4" BOLT
HORIZONTAL GIRT
5" PRECAST CONCRETE SANDWICH PANEL
ALL JOINTS BEVELED 3/8" ON OUTSIDE
CLIP ANGLES WITH 3/4" BOLTS
CHANNEL SUPPORT
CONTINUOUS ANGLE SUPPORT EVERY THIRD PANEL

117.90X

Figure 4-27. —Method of attaching precast panels to steel framework.

PREFABRICATION YARD

Precasting is done either in central prefabrication plants or at site prefabrication plants depending upon the product and its application. On site or temporary prefabrication plants are generally more suitable for military operations. These plants are without roofing and therefore subject to weather and climate considerations. The prefabrication yard is laid out to suit the type and quantity of members to be processed. It must be on firm level ground providing ample working space and access routes. Bridge T-beams, reinforced concrete arches, end walls, and concrete logs are typical members produced at these plants. A schematic layout of a



117.91X

Figure 4-28. –Method of attaching precast panels to concrete framework.

prefabrication yard suitable for producing such members is shown in figure 4-29. A prefabrication unit of this size can be expected to produce approximately 6,000 square feet of precast walls per day. The output will vary according to personnel experience, equipment capabilities, and product requirements.

CONCRETE SAFETY

In concrete construction, as in all types of construction, there is a certain degree of danger involved; so to help you do your concrete work safely we will discuss the various safety precautions concerning concrete.

CONCRETE PLACEMENT AND FORM CONSTRUCTION

Form construction and concrete placement have peculiarities in each job; however, certain natural conditions will prevail in all situations. Wet concrete will always develop hydrostatic pressure and strain on forms. Therefore, all stakes, braces, and other supporting members should be properly secured before placing any concrete.

All nailing should be correctly placed and secured. Careless nailing and exposed nails in formwork are a major cause of accidents.

Personnel subject to "cement poisoning" should have their shirt sleeves rolled down and wear gloves when working with concrete.

A supervisor should check all forms prior to each pour.

If concrete buckets and cranes are used in pouring, each bucket should be provided with a tag line or two, depending on the location. A man should never ride a free swinging concrete bucket during a pour.

Adequate scaffolding should be built to permit men to stand clear of pouring areas.

Tools, particularly hammers, should be inspected frequently.

Mud sills should be placed under shoring that rests in the ground.

Raising of large form panels should not be attempted in heavy gusts of wind, either by hand or by crane.

Only workmen actually engaged in stripping the forms should be permitted in the immediate work area.

Stripped forms should be piled immediately to avoid congestion, exposed nails, and other hazards.

Wires under tension should be cut with caution to avoid backlash.

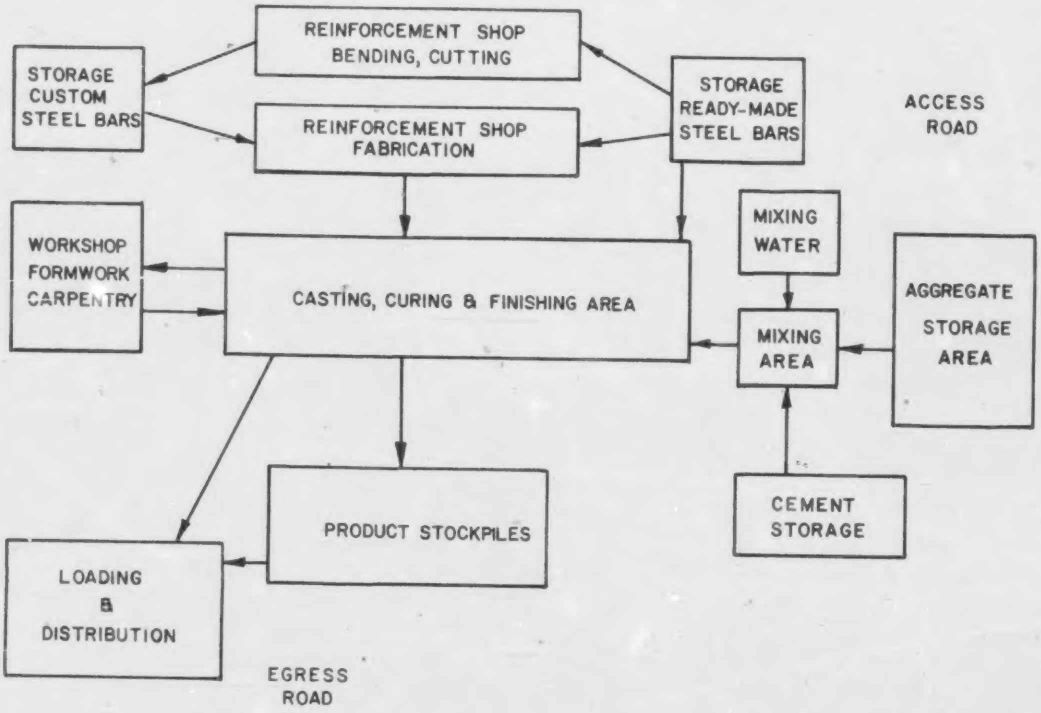
SPOUTING AND CHUTES

All chutes and spouting used in concrete pours should be clean and well supported by proper bracing and guys.

When spouting and chutes run overhead the area beneath must be cleared and barricaded during placing to eliminate the danger of falling concrete or possible collapse causing injuries.

CONCRETE BUCKETS

Concrete buckets must be checked thoroughly before using for proper functioning of discharge gate, sound handles and lift bucket.


REINFORCEMENT SHOP BENDING, CUTTING
STORAGE CUSTOM STEEL BARS
REINFORCEMENT SHOP FABRICATION
STORAGE READY-MADE STEEL BARS
ACCESS ROAD
MIXING WATER
WORKSHOP FORMWORK CARPENTRY
CASTING, CURING & FINISHING AREA
MIXING AREA
AGGREGATE STORAGE AREA
PRODUCT STOCKPILES
CEMENT STORAGE
LOADING & DISTRIBUTION
EGRESS ROAD

117.353

Figure 4-29. —Schematic layout of prefabrication yard.

All hooks that lift and carry concrete buckets should be moused properly to prevent loss of load. Careful inspection of rigging cables should be routine prior to each pour. Closure hooks will not require mousing.

All concrete handling equipment must be thoroughly cleaned at the end of each work period. It must be remenbered that all splattered and set concrete on gear adds to the weight of the dead load cutting the carrying capacity and function of the equipment.

MIXERS AND PAVERS

All gears, chains, and rollers of mixers should be properly guarded. All moving parts should be cleaned and properly serviced so as to give safe performance of the equipment.

Pavers should be equipped with a loud warning bell to be used in advance of any movement or change of direction. During night operations, all equipment should be equipped with sufficient flood and spot lights to make the perimeter of the operations clearly visible. The pouring bucket and the boom of the paver operating controls should have a synchronized warning device to function automatically with the motion of either the boom or the traveling bucket.

Skip loader cables and brakes must be inspected frequently to prevent injuries caused by falling skips.

Whenever working under an elevated skip is unavoidable, the skip must be shored up to prevent it from falling in the event that the brake should fail or be accidentally released.

The mixer operator must never lower the skip without first making sure that there is no one under it.

The area around the mixer must be kept clear.

Dust protection equipment must be issued to men engaged in handling cement, and the men must wear the equipment when so engaged. Men should stand with backs to the wind whenever possible, to prevent cement and sand from being blown into eyes and faces.

Whenever the mixer drum is being cleaned, the switches must be open, and throttles closed, and the control mechanism locked in the OFF position.

Whenever possible, a flagman or watchman should be stationed near the mixer to warn all hands when a batch truck is backing up to the skip. The watchman should use a whistle to warn any personnel in the danger zone. DANGER–KEEP AWAY signs should be placed where they can readily be seen.

HOIST, CRANES, AND DERRICKS

When HOIST, CRANES, and DERRICKS are to be used on a project, the responsibility of operation should be with the Equipment Operator but the responsibility for safe movement, hooking up to the load, and giving of signals should be with the Builder in charge. The supervisory Builder will check all rigging before the signalman will give any signals. The signalman and the Equipment Operator should agree on any special signals used to cover unusual conditions not covered by the newly revised standard hand signals shown in figure 4-30 before any lifting operations begin. Bear in mind that these are the NEWLY REVISED STANDARD HAND SIGNALS CURRENTLY IN USE BY SEABEES. It is therefore important that you fully familiarize yourself with them and use them in your work.

A tagline, or guide rope should be used on loads that are liable to swing while being hoisted. They should be handled by capable men under the direction of the petty officer in charge of the movement.

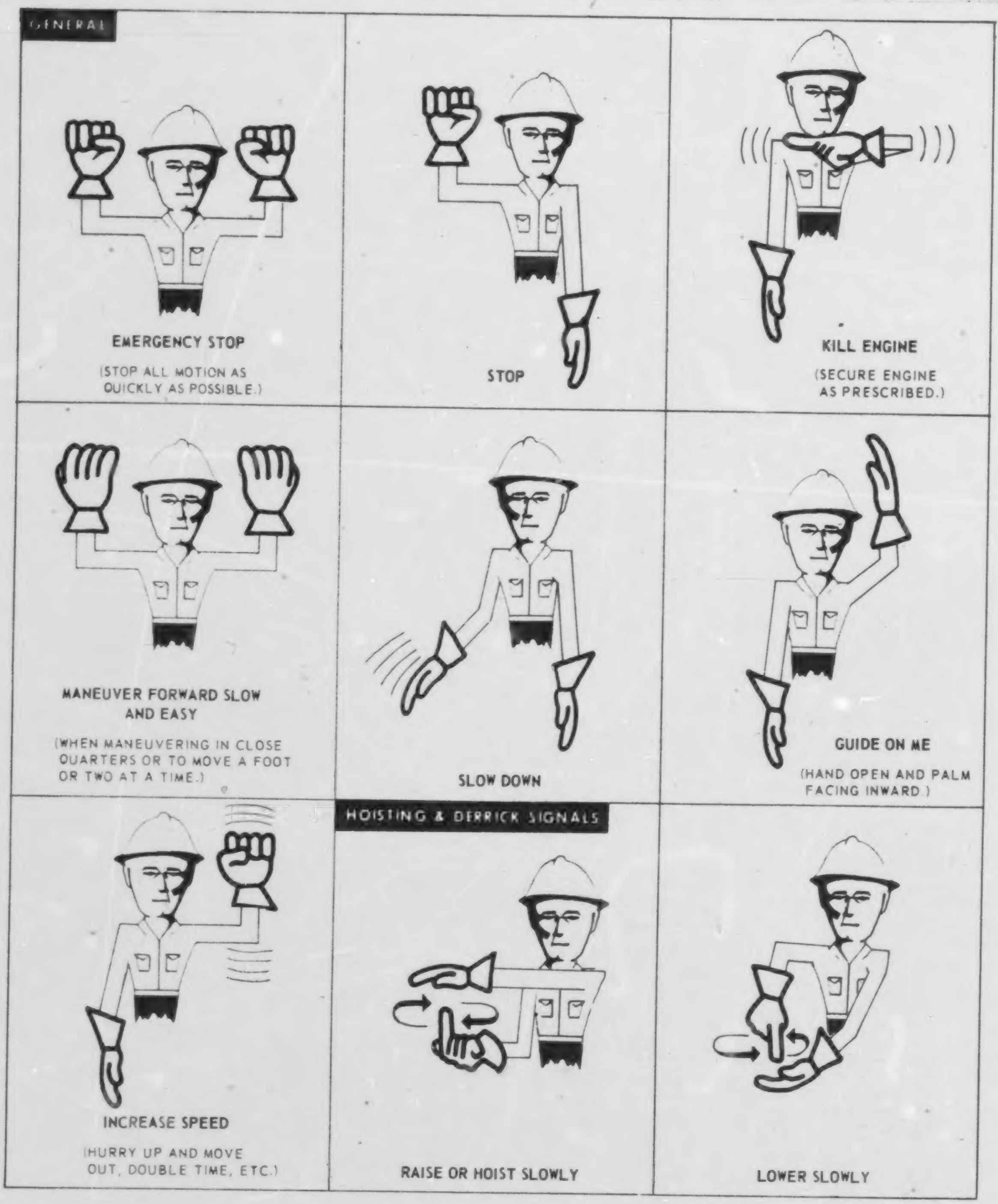
Care should be exercised to prevent any damage to scaffolds or buildings or existing structures.

Personnel should not ride loads or walk under loads that are being lifted.

Loads should not be swung or lifted over men working.

Care should be used to keep crane on good footing at all times.

When using a crane, survey the area and be sure that the boom will be clear of electrical wire at all times. The minimum allowable distance from an energized electrical wire is 10 feet.



GENERAL

EMERGENCY STOP

(STOP ALL MOTION AS QUICKLY AS POSSIBLE.)

STOP

KILL ENGINE

(SECURE ENGINE AS PRESCRIBED.)

MANEUVER FORWARD SLOW AND EASY

(WHEN MANEUVERING IN CLOSE QUARTERS OR TO MOVE A FOOT OR TWO AT A TIME.)

SLOW DOWN

GUIDE ON ME

(HAND OPEN AND PALM FACING INWARD.)

INCREASE SPEED

(HURRY UP AND MOVE OUT, DOUBLE TIME, ETC.)

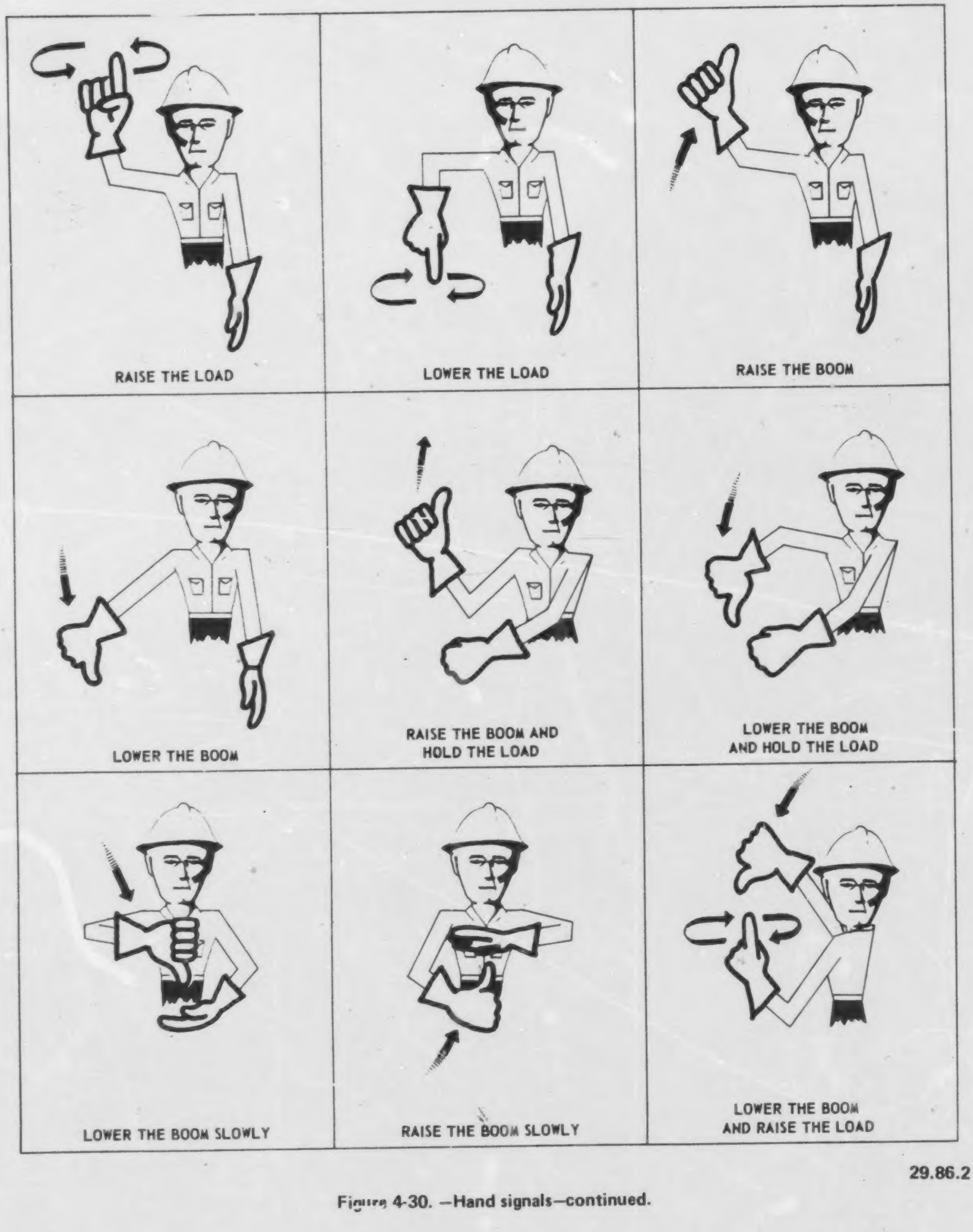
HOISTING & DERRICK SIGNALS

RAISE OR HOIST SLOWLY

LOWER SLOWLY

29.86.1

Figure 4-30. —Hand signals.



RAISE THE LOAD

LOWER THE LOAD

RAISE THE BOOM

LOWER THE BOOM

RAISE THE BOOM AND HOLD THE LOAD

LOWER THE BOOM AND HOLD THE LOAD

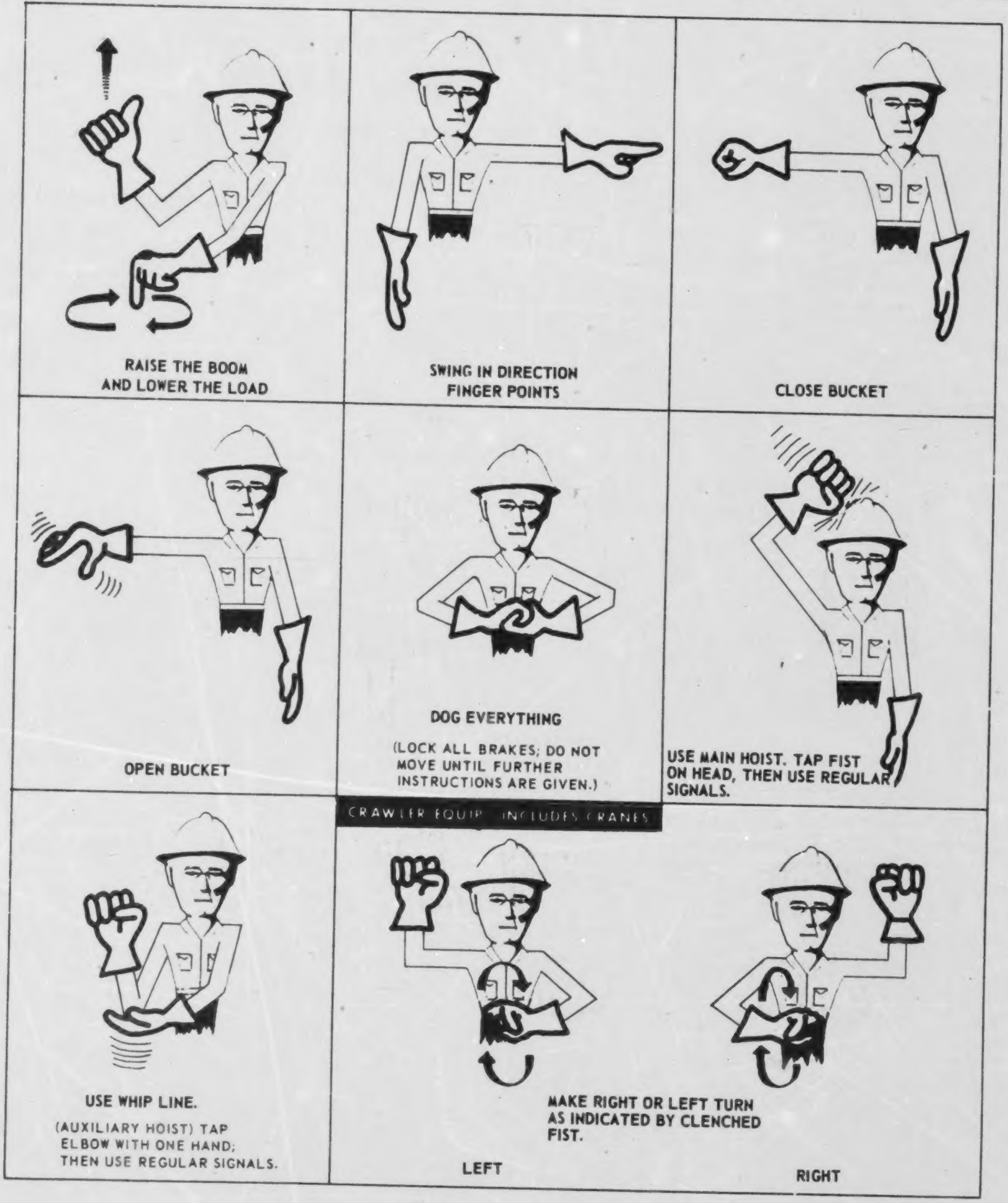
LOWER THE BOOM SLOWLY

RAISE THE BOOM SLOWLY

LOWER THE BOOM AND RAISE THE LOAD

29.86.2

Figure 4-30. —Hand signals—continued.



RAISE THE BOOM AND LOWER THE LOAD

SWING IN DIRECTION FINGER POINTS

CLOSE BUCKET

OPEN BUCKET

DOG EVERYTHING

(LOCK ALL BRAKES; DO NOT MOVE UNTIL FURTHER INSTRUCTIONS ARE GIVEN.)

USE MAIN HOIST. TAP FIST ON HEAD, THEN USE REGULAR SIGNALS.

USE WHIP LINE.

(AUXILIARY HOIST) TAP ELBOW WITH ONE HAND; THEN USE REGULAR SIGNALS.

CRAWLER EQUIP. INCLUDES CRANES

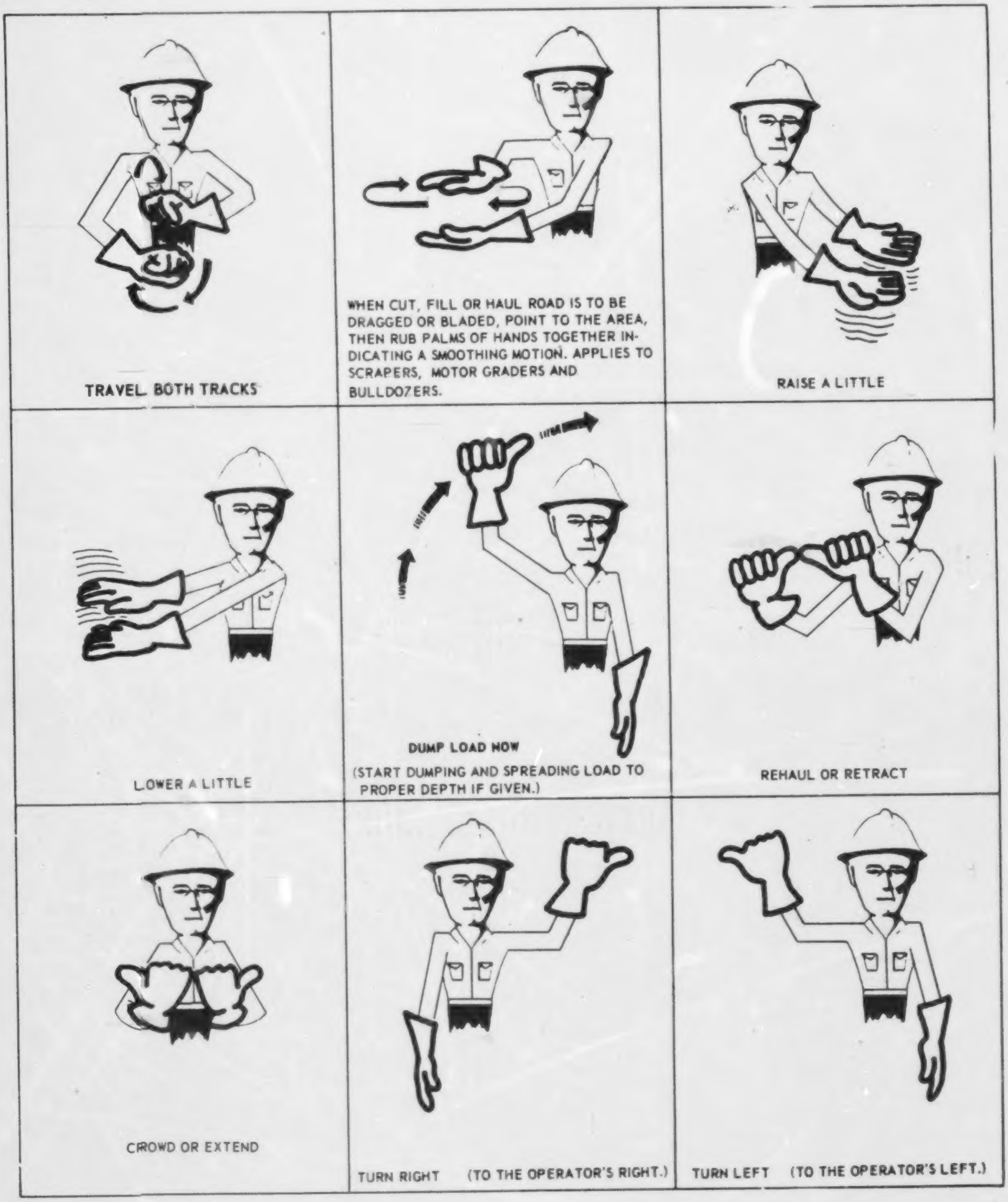
MAKE RIGHT OR LEFT TURN AS INDICATED BY CLENCHED FIST.

LEFT

RIGHT

Figure 4-30. —Hand signals—continued.

29.86.3


TRAVEL BOTH TRACKS
RAISE A LITTLE
LOWER A LITTLE
DUMP LOAD NOW
REHAUL OR RETRACT
CROWD OR EXTEND
TURN RIGHT
TURN LEFT

WHEN CUT, FILL OR HAUL ROAD IS TO BE DRAGGED OR BLADED, POINT TO THE AREA, THEN RUB PALMS OF HANDS TOGETHER INDICATING A SMOOTHING MOTION. APPLIES TO SCRAPERS, MOTOR GRADERS AND BULLDOZERS.

(START DUMPING AND SPREADING LOAD TO PROPER DEPTH IF GIVEN.)

(TO THE OPERATOR'S RIGHT.)

(TO THE OPERATOR'S LEFT.)

29.86.4

Figure 4-30. —Hand signals—continued.

CHAPTER 5

MASONRY CONSTRUCTION

The American Standard Building Code Requirements for Masonry defines masonry as "a built-up construction or combination of building units of such materials as clay, shale, glass, gypsum or stone, set in mortar or plain concrete." However, for our purpose, the commonly accepted definition of masonry, or unit masonry as it is sometimes called, is a construction made up of prefabricated masonry units (such as concrete blocks, or bricks) laid in various ways and joined together with mortar.

Within the SEABEES, there are numerous skill areas for which the demand is limited in comparison with other more common skill areas. One such area, brick masonry, exists in masonry construction. Concrete masonry has become increasingly important as a construction material. Important technological developments in the manufacture and utilization of the units have accompanied the rapid increase in use of concrete masonry in SEABEE construction. This increased use in concrete masonry has resulted in the limited use of brick masonry construction. Therefore, the time and cost involved in training all personnel in the Builder rating to perform skills required for brick masonry construction is impractical. As a result of this trend, a special "C" school course has been developed by which students are trained in all phases of masonry construction. Graduates of this school are called MASONRY TECHNICIANS and assigned the NEC, BU-5902.

The MASONRY TECHNICIAN performs duties related to masonry construction, including bricklaying, blocklaying, stone setting, tile setting, and plastering (portland cement and gypsum). He prepares simple designs, sketches, specifications, and estimates materials, equipment, and manpower requirements; supervises and trains masonry construction crews.

As a supervisor utilizing the skills of a masonry technician on one of your projects, you must be familiar with all aspects of his job in order to ensure successful job completion. On the surface, it might appear that when utilizing the skills of a masonry technician, he can be held responsible for the planning, estimating, scheduling, and overall management for his portion of a project. However, this is only partially true. If you recall in the previous chapter on supervision, you can delegate your authority, but you are the one held responsible for the final product. With this in mind, the following sections which are devoted to brick masonry are so written as to explain the principles of bricklaying and advanced masonry unit construction methods.

BRICK MASONRY

Brick masonry is that type of masonry construction in which units of baked clay or shale of uniform size, small enough to be placed with one hand, are laid in courses with mortar joints to form walls of virtually unlimited length and height. Bricks are kiln-baked from various clay and shale mixtures. The chemical and physical characteristics of the ingredients vary considerably; these and the kiln temperatures combine to produce brick in a variety of colors, hardnesses, and grades. The more common grades are those designed for exposure to Severe, Moderate, and Negligible weather conditions, designated SW, MW, and NW, respectively.

GRADE SW is brick designed to withstand exposure to below-freezing temperatures in a moist climate like that of the northern regions of the United States.

GRADE MW is brick designed to withstand exposure to below-freezing temperatures in a drier climate than that mentioned in the previous paragraph.

GRADE NW is brick primarily intended for interior or backup brick. It may be used exposed, however, in regions where no frost action occurs, or in regions where frost action occurs but the annual rainfall is less than 15 inches.

The dimensions of a U.S. standard building brick are 2-1/2 x 3-3/4 x 8 inches. The actual dimensions of brick may vary a little because of shrinkage during burning.

TYPES OF BRICKS

There are many types of brick. Some are different in formation and composition while others vary according to their use. Some commonly used types of brick are:

BUILDING brick, formerly called common brick, is made of ordinary clays or shales and burned in the usual manner in the kilns. These bricks do not have special scorings or markings and are not produced in any special color or surface texture. Building brick is also known as hard and kiln run brick. It is used generally for the backing courses in solid or cavity brick walls. The harder and more durable kinds are preferred for this purpose.

FACE bricks are used in the exposed face of a wall and are higher quality units than backup brick. They have better durability and appearance. The most common colors of face brick are various shades of brown, red, gray, yellow, and white.

CLINKER bricks are bricks that have been overburned in the kiln. This type of brick is usually hard and durable and may be irregular in shape. Rough hard corresponds to the clinker classification.

PRESS bricks are made by the dry press process. The dry press process gives the brick regular smooth faces, sharp edges, and perfectly square corners. Ordinarily, all press bricks are used as face brick.

GLAZED brick has one surface of each brick glazed in white or other color. The ceramic glazing consists of mineral ingredients which fuse together in a glass-like coating during burning. This type of brick is particularly suited for walls or partitions in hospitals, dairies, laboratories or other buildings where cleanliness and ease of cleaning is necessary.

FIRE brick is made of a special type of fire clay which will withstand the high temperatures of fireplaces, boilers and similar usages without cracking or decomposing. Fire brick is generally larger than regular structural brick and often it is hand molded. The standard size is 9 x 4-1/2 x 2-1/2 inches.

SILICA brick is made up entirely of silicious materials. Although highly heat resistant, it should not be used if it is to be alternately heated and cooled. Silica brick is laid without mortar. They fit so closely that they fuse together at the joints when subjected to high temperatures.

CORED bricks are bricks made with holes extending through their beds to reduce weight. There is no significant difference between the strength of walls constructed with cored brick and those constructed with solid brick. Resistance to moisture penetration is about the same for both types of walls. The most easily available brick that will meet requirements and specifications should be used whether the brick is cored or solid.

MORTAR FOR BRICK MASONRY

Mortar is used to bond the brick together and unless properly mixed and applied will be the weakest part of brick masonry. Both the strength and resistance to rain penetration of brick masonry walls are dependent to a great degree on the strength of the bond. Water in the mortar is essential to the development of bond, and if the mortar contains insufficient water the bond will be weak and spotty. When brick walls leak it is usually through the mortar joints. Irregularities in dimensions and shape of bricks are corrected by the mortar joint.

Mortar should be plastic enough to work with a trowel. The properties of mortar depend largely upon the type of sand used in it. Clean, sharp sand produces excellent mortar. Too much sand in mortar will cause it to segregate, drop off the trowel, and weather poorly.

The selection of mortar for brick construction depends on the use requirements of the structure. For example, the recommended mortar for use in laying up interior non-load-bearing partitions would not be satisfactory for foundation walls. In many cases, the masonry technician relies upon a fixed proportion of cement, lime and sand to provide a satisfactory mortar. (See figure 5-1.) The following types of mortar are proportioned on a volume basis:

TYPE M is 1 part portland cement, 1/4 part hydrated lime or lime putty, and 3 parts sand, or 1 part portland cement, 1 part type II masonry cement, and 6 parts sand. This mortar is suitable for general use and is recommended specifically for masonry below grade and in contact with earth, such as foundations, retaining walls, and walks.

TYPE S is 1 part portland cement, 1/2 part hydrated lime or lime putty, and 4-1/2 parts sand, or 1/2 part portland cement, 1 part type II masonry cement and 4-1/2 parts sand. This mortar is also suitable for general use and is recommended where high resistance to lateral forces is required.

TYPE N is 1 part portland cement, 1 part hydrated lime or lime putty, and 6 parts sand, or 1 part type II masonry cement and 3 parts sand. This mortar is suitable for general use in exposed masonry above grade and is recommended specifically for exterior walls subjected to severe exposures.

Type O is 1 part portland cement, 2 parts hydrated lime or lime putty, and 9 parts sand, or 1 part type I or type II masonry cement and 3 parts sand. This mortar is recommended for load-bearing walls of solid units where the compressive stresses do not exceed 100 pounds per square inch and the masonry will not be subjected to freezing and thawing in the presence of excessive moisture.

RESISTANCE TO WEATHERING

The resistance of masonry walls to weathering depends almost entirely upon their resistance to water penetration because freezing and thawing action is virtually the only type of weathering that affects brick masonry. With the best workmanship, it is possible to build brick walls that will resist the penetration of rain water during a storm lasting as long as 24 hours accompanied by a 50- to 60-mile-per-hour wind. In most construction, it is unreasonable to expect the type of workmanship required to build a wall that will allow no water penetration. It is advisable to provide some means of taking

Proportions by Volume

Type of service	Cement	Hydrated lime or lime putty	Mortar sand in damp, loose condition
For ordinary service	1--masonry cement*	--	2 to 3
	or		
	1--portland cement	1 to 1 1/4	4 to 6
Subject to extremely heavy loads, violent winds, earthquakes or severe frost action. Isolated piers.	1--masonry cement* plus 1--portland cement	--	4 to 6
	or		
	1--portland cement	0 to 1/4	2 to 3

*Tentative ASTM Specification C 91, Type II.

117.188(117F)

Figure 5-1. —Recommended mortar mixes.

care of moisture after it has penetrated the brick masonry. Properly designed flashing and cavity walls are two ways of handling moisture that has entered the wall.

Important factors in preventing the entrance of water are tooled mortar joints and caulking around windows and door frames.

The joints between the brick must be solidly filled, especially in the face tier. Slushing or grouting the joints after the brick has been laid does not completely fill the joint. The mortar joint should be tooled to a concave surface before the mortar has had a chance to set up. In tooling, sufficient force should be used to press the mortar tight against the brick on both sides of the mortar joint.

Mortar joints that are tightly bonded to the brick have been shown to have greater resistance to moisture penetration than joints not tightly bonded to the brick.

GENERAL CHARACTERISTICS OF BRICK MASONRY

Solid brick masonry walls provide very little insulation against heat and cold. A cavity wall or a brick wall backed with hollow clay tile has much better insulating value.

Because brick walls are exceptionally massive, they have good sound-insulating properties. In general, the heavier the wall, the better will be its sound-insulating value; however, there is no appreciable increase in sound insulation by a wall more than 12 inches thick as compared to a wall between 10 and 12 inches thick. The expense involved in constructing a thicker wall merely to take advantage of the slight increase is too excessive to be worthwhile. Dividing the wall into two or more layers, as in the case of a cavity wall, will increase its resistance to the transmission of sound from one side of the wall to the other. Brick walls are poor absorbers of sound originating within the walls and reflect much of it back into the structure. Sounds caused by impact, as when the wall is struck with a hammer, will travel a great distance along the wall.

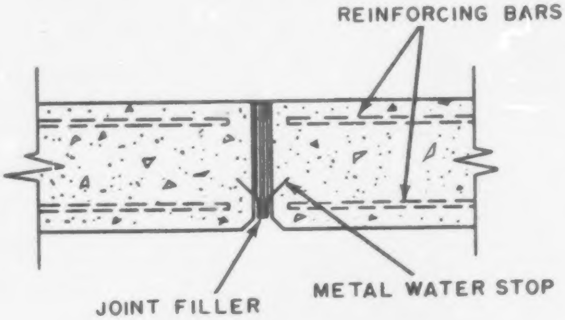
Brick masonry expands and contracts with temperature change. Walls up to a length of 200 feet do not need expansion joints. Longer walls need an expansion joint for every 200 feet of wall. The joint can be made as shown in figure 5-2. A considerable amount of the expansion and contraction is taken up in the wall itself. For this reason, the amount of movement that theoretically takes place does not actually occur.

The resistance of brick to abrasion depends largely upon its compressive strength, related to the degree of burning. Well-burned brick have excellent wearing qualities.

The weight of brick varies from 100 to 150 pounds per cubic foot depending upon the nature of the materials used in making the brick and the degree of burning. Well-burned brick are heavier than under-burned brick.

BRICKLAYING METHODS

Good bricklaying procedure depends on good workmanship and efficiency. Means of obtaining good workmanship are treated below. Efficiency involves doing the work with the fewest possible motions. The masonry technician studies his own operations to determine those motions that are unnecessary. Each motion should have a purpose and should accomplish a definite result. After learning the fundamentals, every masonry technician develops his own methods for achieving maximum efficiency. The work must be arranged in such a way that the masonry technician is continually supplied with brick and mortar. The scaffolding required must be planned before the work begins. It must be built in such a way as to cause the least interference



133.287

Figure 5-2. –Expansion joint for wall.

with other workmen. Masons' tools and equipment used in bricklaying are generally the same as, or similar to, those used in concrete block masonry construction discussed in *Builder 3 & 2.*

Types of Bonds

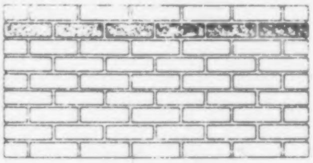
The word "bond," when used in reference to masonry, may have three different meanings:

STRUCTURAL BOND is the method by which individual masonry units are interlocked or tied together to cause the entire assembly to act as a single structural unit. Structural bonding of brick and tile walls may be accomplished in three ways. First, by overlapping (interlocking) the masonry units, second by the use of metal ties imbedded in connecting joints, and third by the adhesion of grout to adjacent wythes of masonry.

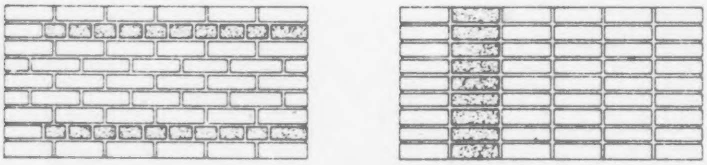
MORTAR BOND is the adhesion of the joint mortar to the masonry units or to the reinforcing steel.

PATTERN BOND is the pattern formed by the masonry units and the mortar joints on the face of a wall. The pattern may result from the type of structural bond used or may be purely a decorative one in no way related to the structural bond. There are five basic pattern bonds in common use today as shown in figure 5-3: Running bond, Common or American bond, Flemish bond, English bond, and Block or Stack bond.

RUNNING BOND.–This is the simplest of the basic pattern bonds; the running bond consists of all stretchers. Since there are no

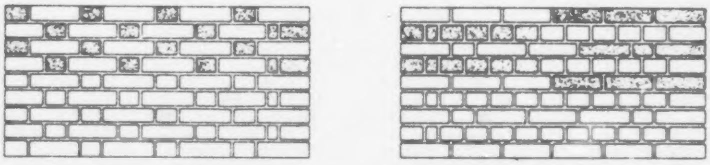


RUNNING



COMMON

STACK



FLEMISH

ENGLISH

133.288 (117F)

Figure 5-3. –Some types of brick masonry bond.

headers used in this bond, metal ties are usually used. Running bond is used largely in cavity wall construction and veneered walls of brick, and often in facing tile walls where the bonding may be accomplished by extra width stretcher tile.

COMMON OR AMERICAN BOND.–Common bond is a variation of running bond with a course of full length headers at regular intervals. These headers provide structural bonding as well as pattern. Header courses usually appear at every fifth, sixth, or seventh course depending on the structural bonding requirements. In laying out any bond pattern it is very important that the corners be started correctly. For common bond, a "three-quarter" brick must start each header course at the corner. Common bond may be varied by using a Flemish header course.

FLEMISH BOND.–In this bond, each course of brick is made up of alternate stretchers and headers, with the headers in alternate courses centered over the stretchers in the intervening courser. Where the headers are not used for the structural bonding, they may be obtained by using half brick, called blind-headers.

ENGLISH BOND.–English bond is composed of alternate courses of headers and stretchers. The headers are centered on the stretchers and joints between stretchers. The vertical (head) joints between stretchers in all courses line up vertically. Blind headers are used in courses which are not structural bonding courses.

BLOCK OR STACK BOND.–This bond is purely a pattern bond. There is no overlapping of the units, all vertical joints being aligned. Usually this pattern is bonded to the backing with rigid steel ties, but when 8 inch thick stretcher units are available, they may be used. In large wall areas and in load-bearing construction it is advisable to reinforce the wall with steel pencil rods placed in the horizontal mortar joints. The vertical alignment requires dimensionally accurate units, or carefully prematched units, for each vertical joint alignment. Variety in pattern may be achieved by numerous combinations and modifications of the basic patterns shown.

Masonry Terms

Specific terms are used to describe the various positions of masonry units and mortar joints in a wall (figure 5-4):

Course. One of the continuous horizontal layers (or rows) of masonry which, bonded together, form the masonry structure.

Wythe. A continuous vertical 4-inch or greater section or thickness of masonry as the thickness of masonry separating flues in a chimney.

Stretcher. A masonry unit laid flat with its longest dimension parallel to the face of the wall.

Header. A masonry unit laid flat with its longest dimension perpendicular to the face of the wall. It is generally used to tie two wythes of masonry together.

Rowlock. A brick laid on its edge (face).

Bull-Stretcher. A rowlock brick laid with its longest dimension parallel to the face of the wall.

Bull-Header. A rowlock brick laid with its longest dimension perpendicular to the face of the wall.

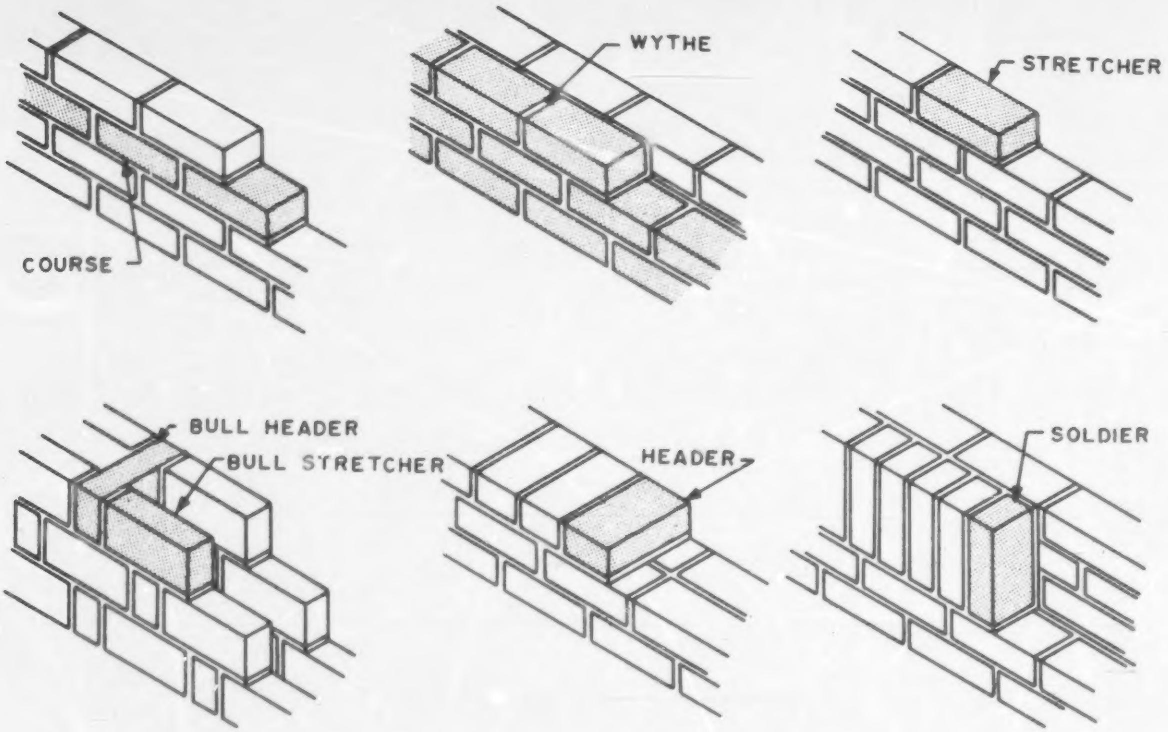
Soldier. A brick laid on its end so that its longest dimension is parallel to the vertical axis of the face of the wall.

Metal Ties

Metal ties can be used to tie the brick on the outside face of the wall to the backing courses. These are used when no header courses are installed such as in a cavity wall (explained later in this chapter). They are not as satisfactory as header courses. Typical metal ties are shown in figure 5-5.

FLASHING

Flashing is the impervious membrane placed at certain places in brick masonry for the purpose of excluding water or to collect any moisture that does penetrate the masonry, directing it to the outside of the wall. Flashing is installed at the head and sill of window openings and, in some buildings, at the intersection of the wall



133.289

Figure 5-4. —Masonry units and mortar joints.

and roof. Where chimneys pass through the roof, the flashing should extend entirely through the chimney wall and turn up for a distance of 1 inch against the flue lining.

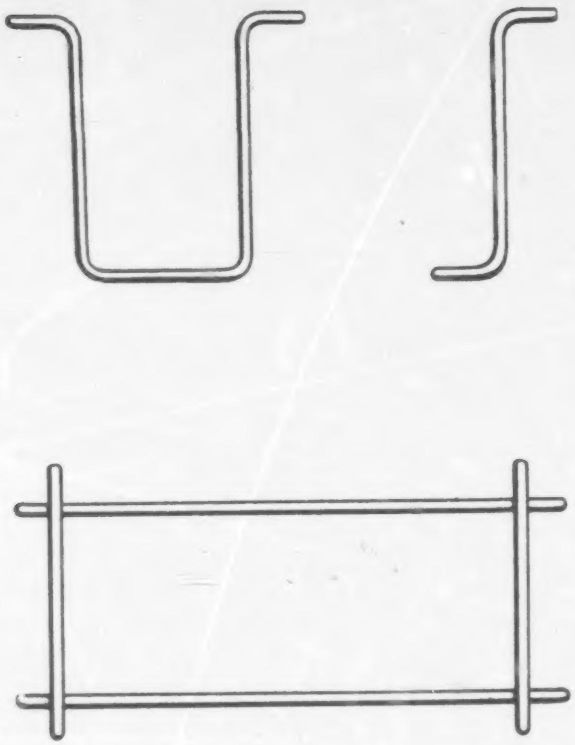
The edges of the flashing are turned up as shown in figure 5-6 to prevent drainage into the wall. Flashing is always installed in mortar joints. Drainage for the wall above the flashing is provided by placing 1/4-inch cotton-rope drainage wicks in the mortar joint just above the flashing membrane at 18-inch spacings. Drainage may also be provided by holes left after dowels placed in the proper mortar joint are removed.

Flashing Materials

Copper, lead, aluminum, and bituminous roofing paper may be used for the flashing membrane. Copper is generally preferred but it will stain the masonry when it weathers. If the staining is undesirable, lead-coated copper should be used. Bituminous roofing papers are the cheapest, but they are not as durable and may have to be replaced for permanent construction. The cost of replacement is many times the cost of installing high-quality flashing. Corrugated copper flashing sheets are available that produce a good bond with the mortar. These sheets have interlocking watertight joints at points of overlap.

Installation of Flashing

In placing flashing, a 1/2-inch thick bed of mortar is spread on top of the brick and the flashing sheet pushed firmly down into the mortar. The brick or sill that goes on top of the flashing is forced into a 1/2-inch thick mortar bed spread on the flashing.



127.77(133F)

Figure 5-5. –Metal ties.

Details for the proper installation of flashing at the head and at the sill of a window are shown in figure 5-6. Note that at the steel lintel the flashing goes in under the face tier of brick, then back of the face tier, and finally over the top of the lintel.

The flashing required at the intersection of the roof and wall is shown in figure 5-7 and is always installed to prevent leakage between the roof and the wall. The upper end of the flashing is fitted and calked into the groove of the raggle block.

Joint Finishes

Exterior surfaces of mortar joints are finished to make the brickwork more waterproof and to improve the appearance. There are several types of joint finishes, as shown in figure 5-8. The more important of these are discussed below. When joists are cut flush with the brick and not finished, cracks are immediately apparent between the brick and the mortar. Although these cracks are not deep, they are undesirable and can be eliminated by finishing or tooling the joint. In every case, the mortar joint should be finished before the mortar has hardened to any appreciable extent.

The best joints from the standpoint of weather-tightness are the CONCAVE and "V" type joints. These joints are made with a special tool after the excess mortar has been removed with the trowel. The tool should be slightly larger than the joint. Force is used to press the mortar tight against the brick on both sides of the mortar joint.

The FLUSH joint (figure 5-8) is made by keeping the trowel almost parallel to the face of the wall while drawing the point of the trowel along the joint.

A WEATHER joint sheds water more easily from the surface of the wall and is formed by pushing downward on the mortar with the top edge of the trowel.

BRICK CONSTRUCTION

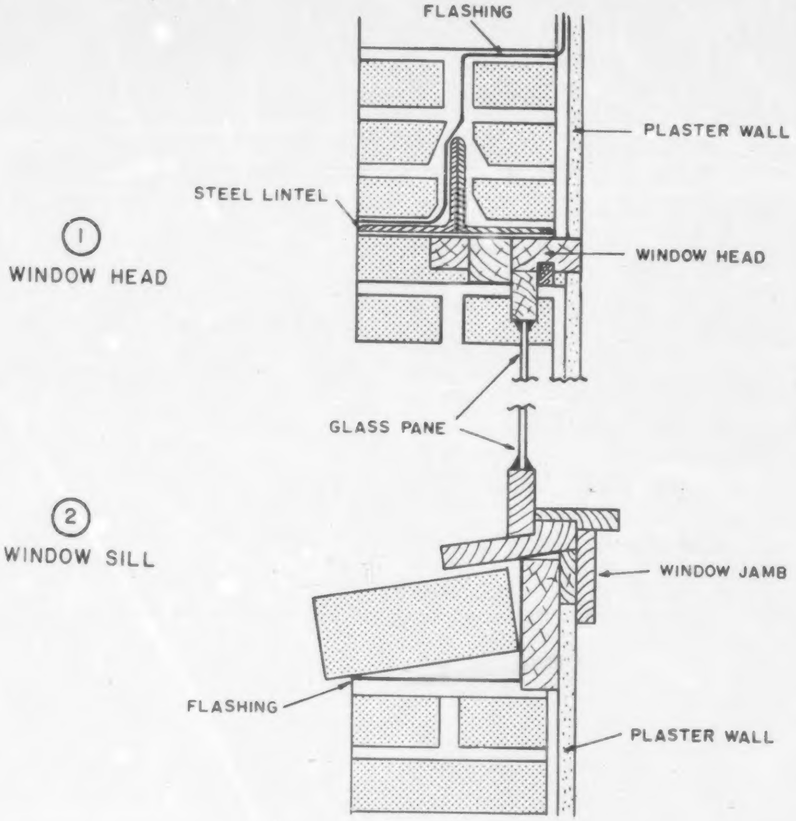
An attractive brick construction depends upon the interpretation of the plans and the abilities of the masonry technicians and their helpers, usually referred to as bricktenders. Whether building an 8-inch or 12-inch wall, they must be able to work together and carry out their duties properly.

Masonry Technician's Duties

The masonry technician does the actual laying of the brick. It is his responsibility to lay out the job so that the finished masonry will be properly done. In construction involving walls, he must see that the walls are plumb and the courses level.

Bricktender's Duties

The bricktender mixes mortar, carries brick and mortar to the masonry technician laying



45.488:.489

Figure 5-6. —Flashing at window opening.

brick, and keeps him supplied with these materials at all times. He fills the mortar board and places it in a position convenient for the masonry technician. He assists in the laying out and, at times, such as during rapid backup bricklaying, he may lay out brick in a line on an adjacent course so that the masonry technician needs to move each brick only a few inches in laying backup work.

Wetting brick is also the duty of the bricktender. There are four reasons for wetting brick just before they are laid:

1. There will be a better bond between the brick and the mortar.

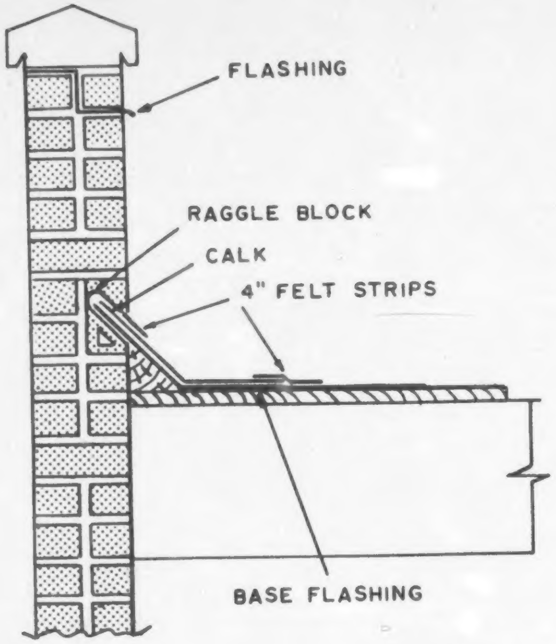
2. The water will wash dust and dirt from the surface of the brick. Mortar adheres better to a clean brick.

3. If the surface of the brick is wet, the mortar spreads more evenly under it.

4. A dry brick may absorb water from the mortar rapidly. This is particularly bad when mortar containing portland cement is used. In order for cement to harden properly, sufficient moisture must be present to complete the hydration of the cement. If the brick robs the mortar of too much water, there will not be enough left to hydrate the cement properly.

Footings

A footing is required under a wall when the bearing capacity of the supported soil is not sufficient to withstand the wall load without a further means of redistribution. The footing must be wider than the thickness of the wall. The required footing width and thickness for walls of considerable height or for walls that are



45.490

Figure 5-7. —Flashing at intersection of roof and wall.

to carry a heavy load should be determined by a qualified Builder. Every footing should be below the frostline in order to prevent heaving and settlement of the foundation. For the usual one-story building with an 8-inch-thick wall, a footing 16 inches wide and approximately 8 inches thick is usually enough. Although brickwork footings are satisfactory, footings are normally concrete, leveled on top to receive the brick or stone foundation wall. As soon as the subgrade is prepared, the masonry technician should place a bed of mortar about 1 inch thick on the subgrade to take up all irregularities. The first course of the foundation is laid on this bed of mortar. The other courses are then laid on this first course.

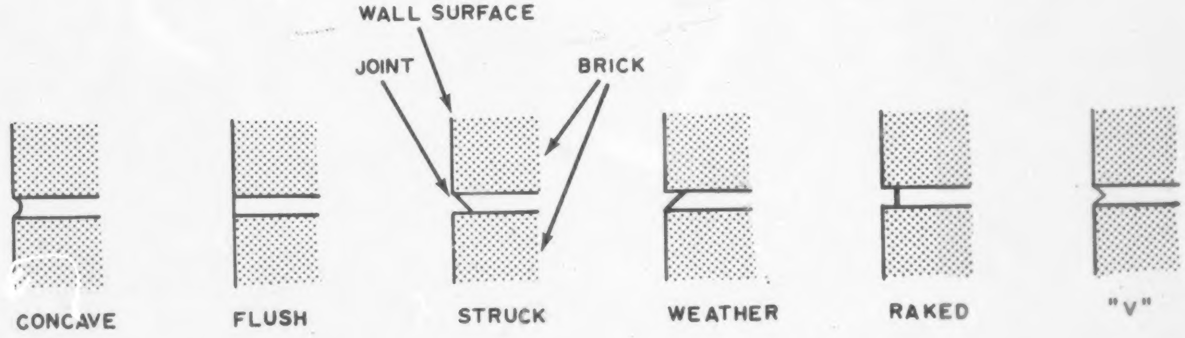
Eight-Inch Common Bond Brick Wall

For a wall of given length, a slight adjustment in the width of head joists is required so that the total quantity of brick, or the total quantity including one-half brick, will just make up the length. The first brick is laid on the foundation without mortar to check for spacing, as shown in figure 5-9. Tables 5-1, 5-2, and 5-3 give the number of courses and horizontal joints required for a given wall height.

The corners or leads are laid first using a sufficient mortar bed to obtain approximately a 1/2-inch mortar joint. Then the space in between is laid up. Brick is laid very similar to concrete block which is discussed in detail in *Builder 3 & 2*. A step-by-step illustration is given in figures 5-10 through 5-14.

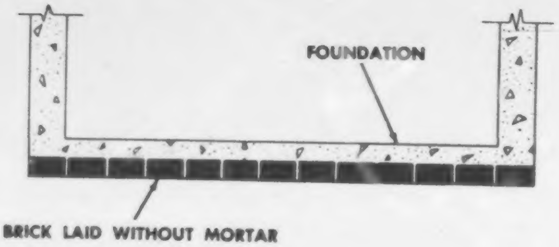
Brick Quantity Estimate

To estimate quantities of materials and labor required for brickwork, you must first calculate



133.305

Figure 5-8. —Joint finishes.



133.308
Figure 5-9. —Determination of vertical brick joints and number of bricks in one course.

the NET surface area by deducting the total area of all openings. Table 5-4 shows the material and labor requirements for 1,000 sq ft of 1/2" joint brick wall under ordinary conditions. Table 5-5 shows the material and labor requirements for brickwork footings and piers.

Suppose you need to know the number of bricks required for 35 sq ft of 8" basement wall. Table 5-4 indicates that it takes 12,706 bricks to make 1,000 sq ft of wall this type. If it takes 12,706 bricks to make 1,000 sq ft, it takes x bricks to make 35 sq ft, and your equation reads:

$$12{,}706:1{,}000::x:35$$

Consequently, $1{,}000x = (35 \times 12{,}706)$, or 444,710, and $x = 444{,}710/1{,}000$. How do you divide anything by 1,000? Simply by moving the decimal point three spaces to the left. The number of bricks required for 35 sq ft of wall in this case is, therefore, 444.7.

For face brick showing 8" by 2-1/4" on the face, with 3/8" mortar joints, it takes slightly more than 6-1/2 bricks to cover a square foot of wall. Consequently, to determine face brick requirements, you multiply the net area of wall to be faced by 6-1/2, and add a few over, depending on the size of the area. Face brick quantities should be subtracted, of course, from the total brick requirements found as described above.

Ingredient amounts required per cu yd of mortar will depend upon the mix formula of the mortar. Proportions of cement, lime, and sand in mortar range from 1:0.05:2 all the way to 1:2:9. It takes 13 sacks of cement, 26 lb of lime,

Table 5-1. —Height of Courses: 2 1/4-Inch Brick, 3/8-Inch Joint

Courses	Height	Courses	Height	Courses	Height	Courses	Height	Courses	Height
1	0′ 2⅝″	21	4′ 7⅛″	41	8′ 11⅝″	61	13′ 4⅛″	81	17′ 8⅝″
2	0′ 5¼″	22	4′ 9¾″	42	9′ 2¼″	62	13′ 6¾″	82	17′ 11¼″
3	0′ 7⅞″	23	5′ 0⅜″	43	9′ 4⅞″	63	13′ 9⅜″	83	18′ 1⅞″
4	0′ 10½″	24	5′ 3″	44	9′ 7½″	64	14′ 0″	84	18′ 4½″
5	1′ 1⅛″	25	5′ 5⅝″	45	9′ 10⅛″	65	14′ 2⅝″	85	18′ 7⅛″
6	1′ 3¾″	26	5′ 8¼″	46	10′ 0¾″	66	14′ 5¼″	86	18′ 9¾″
7	1′ 6⅜″	27	5′ 10⅞″	47	10′ 3⅜″	67	14′ 7⅞″	87	19′ 0⅜″
8	1′ 9″	28	6′ 1½″	48	10′ 6″	68	14′ 10½″	88	19′ 3″
9	1′ 11⅝″	29	6′ 4⅛″	49	10′ 8⅝″	69	15′ 11⅛″	89	19′ 5⅝″
10	2′ 2¼″	30	6′ 6¾″	50	10′ 11¼″	70	15′ 3¾″	90	19′ 8¼″
11	2′ 4⅞″	31	6′ 9⅜″	51	11′ 1⅞″	71	15′ 6⅜″	91	19′ 10⅞′
12	2′ 7½″	32	7′ 0″	52	11′ 4½″	72	15′ 9″	92	20′ 1½″
13	2′ 10⅛″	33	7′ 2⅝″	53	11′ 7⅛″	73	15′ 11⅝″	93	20′ 4⅛″
14	3′ 0¾″	34	7′ 5¼″	54	11′ 9¾″	74	16′ 2¼″	94	20′ 6¾″
15	3′ 3⅜″	35	7′ 7⅞″	55	12′ 0⅜″	75	16′ 4⅞″	95	20′ 9⅜″
16	3′ 6″	36	7′ 10½″	56	12′ 3″	76	16′ 7½″	96	21′ 0″
17	3′ 8⅝″	37	8′ 1⅛″	57	12′ 5⅝″	77	16′ 10⅛″	97	21′ 2⅝″
18	3′ 11¼″	38	8′ 3¾″	58	12′ 8¼″	78	17′ 0¾″	98	21′ 5¼″
19	4′ 1⅞″	39	8′ 6⅜″	59	12′ 10⅞″	79	17′ 3⅜″	99	21′ 7⅞″
20	4′ 4½″	40	8′ 9″	60	13′ 1½″	80	17′ 6″	100	21′ 10½″

133.331

Table 5-2. —Height of Courses: 2 1/4-Inch Brick, 1/2-Inch Joint

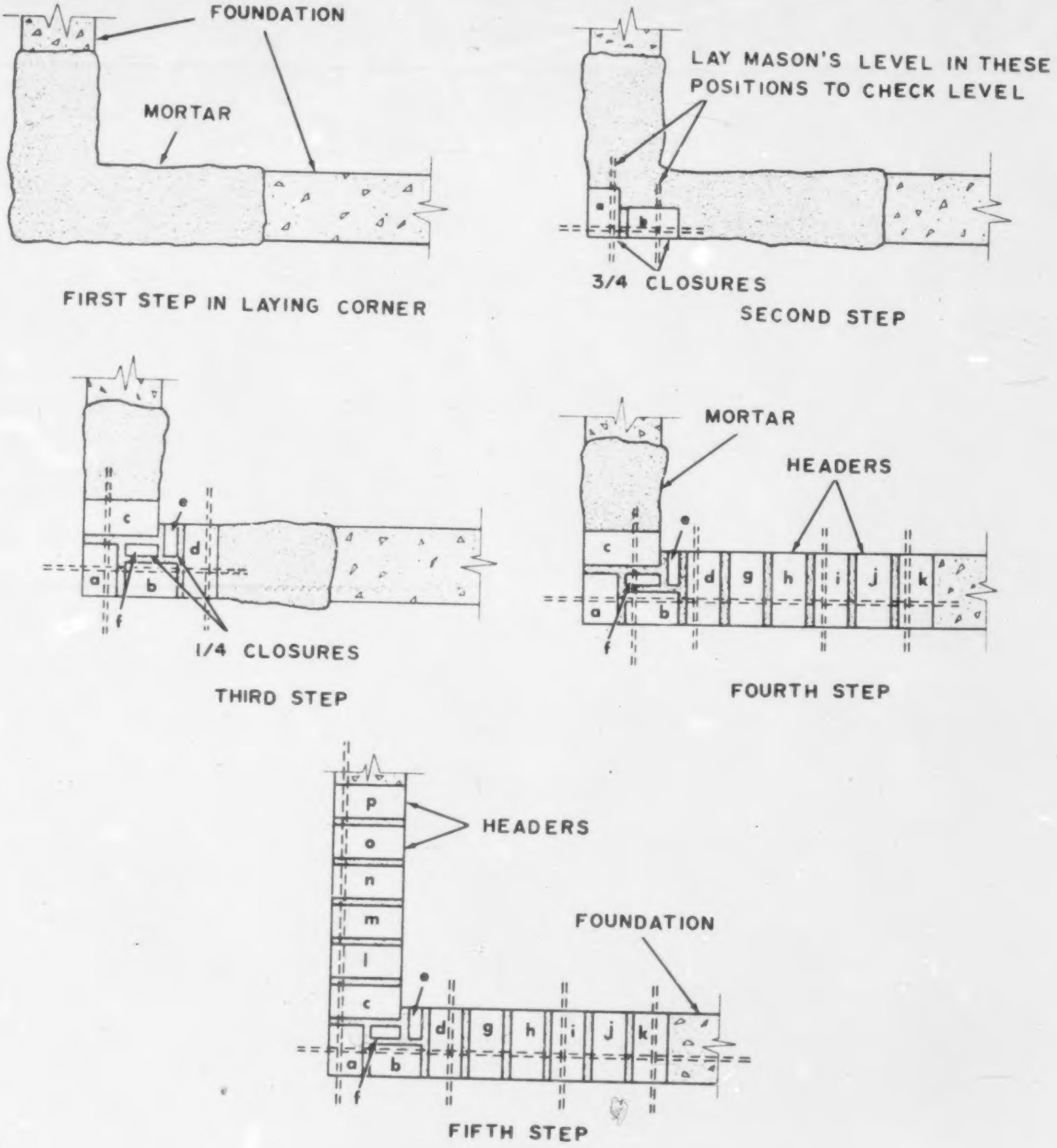
Courses	Height	Courses	Height	Courses	Height	Courses	Height	Courses	Height
1	0′ 2¾″	21	4′ 9¾″	41	9′ 4¾″	61	13′ 11¾″	81	18′ 6¾″
2	0′ 5½″	22	5′ 0½″	42	9′ 7½″	62	14′ 2½″	82	18′ 9½″
3	0′ 8¼″	23	5′ 3¼″	43	9′ 10¼″	63	14′ 5¼″	83	19′ 0¼″
4	0′ 11″	24	5′ 6″	44	10′ 1″	64	14′ 8″	84	19′ 3″
5	1′ 1¾″	25	5′ 8¾″	45	10′ 3¾″	65	14′ 10¾″	85	19′ 5¾″
6	1′ 4½″	26	5′ 11½″	46	10′ 6½″	66	15′ 1½″	86	19′ 8½″
7	1′ 7¼″	27	6′ 2¼″	47	10′ 9¼″	67	15′ 4¼″	87	19′ 11¼″
8	1′ 10″	28	6′ 5″	48	11′ 0″	68	15′ 7″	88	20′ 2″
9	2′ 0¾″	29	6′ 7¾″	49	11′ 2¾″	69	15′ 9¾″	89	20′ 4¾″
10	2′ 3½″	30	6′ 10½″	50	11′ 5½″	70	16′ 0½″	90	20′ 7½″
11	2′ 6¼″	31	7′ 1¼″	51	11′ 8¼″	71	16′ 3¼″	91	20′ 10¼″
12	2′ 9″	32	7′ 4″	52	11′ 11″	72	16′ 6″	92	21′ 1″
13	2′ 11¾″	33	7′ 6¾″	53	12′ 1¾″	73	16′ 8¾″	93	21′ 3¾″
14	3′ 2½″	34	7′ 9½″	54	12′ 4½″	74	16′ 11½″	94	21′ 6½″
15	3′ 5¼″	35	8′ 0¼″	55	12′ 7¼″	75	17′ 2¼″	95	21′ 9¼″
16	3′ 8″	36	8′ 3″	56	12′ 10″	76	17′ 5″	96	22′ 0″
17	3′ 10¾″	37	8′ 5¾″	57	13′ 0¾″	77	17′ 7¾″	97	22′ 2¾″
18	4′ 1½″	38	8′ 8½″	58	13′ 3½″	78	17′ 10½″	98	22′ 5½″
19	4′ 4¼″	39	8′ 11¼″	59	13′ 6¼″	79	18′ 1¼″	99	22′ 8¼″
20	4′ 7″	40	9′ 2″	60	13′ 9″	80	18′ 4″	100	22′ 11″

133.332

Table 5-3. —Height of Courses: 2 1/4-Inch Brick, 5/8-Inch Joint

Courses	Height	Courses	Height	Courses	Height	Courses	Height	Courses	Height
1	0′ 2⅞″	21	5′ 0⅜″	41	9′ 9⅞″	61	14′ 7⅜″	81	19′ 4⅞″
2	0′ 5¾″	22	5′ 3¼″	42	10′ 0¾″	62	14′ 10¼″	82	19′ 7¾″
3	0′ 8⅝″	23	5′ 6⅛″	43	10′ 3⅝″	63	15′ 1⅛″	83	19′ 10⅝″
4	0′ 11½″	24	5′ 9″	44	10′ 6½″	64	15′ 4″	84	20′ 1½″
5	1′ 2⅜″	25	5′ 11⅞″	45	10′ 9⅜″	65	15′ 6⅞″	85	20′ 4⅜″
6	1′ 5¼″	26	6′ 2¾″	46	11′ 0¼″	66	15′ 9¾″	86	20′ 7¼″
7	1′ 8⅛″	27	6′ 5⅝″	47	11′ 3⅛″	67	16′ 0⅝″	87	20′ 10⅛″
8	1′ 11″	28	6′ 8½″	48	11′ 6″	68	16′ 3½″	88	21′ 1″
9	2′ 1⅞″	29	6′ 11⅜″	49	11′ 8⅞″	69	16′ 6⅜″	89	21′ 3⅞″
10	2′ 4¾″	30	7′ 2¼″	50	11′ 11¾″	70	16′ 9¼″	90	21′ 6¾″
11	2′ 7⅝″	31	7′ 5⅛″	51	12′ 2⅝″	71	17′ 0⅛″	91	21′ 9⅝″
12	2′ 10½″	32	7′ 8″	52	12′ 5½″	72	17′ 3″	92	22′ 0½″
13	3′ 1⅜″	33	7′ 10⅞″	53	12′ 8⅜″	73	17′ 5⅞″	93	22′ 3⅜″
14	3′ 4¼″	34	8′ 1¾″	54	12′ 11¼″	74	17′ 8¾″	94	22′ 6¼″
15	3′ 7⅛″	35	8′ 4⅝″	55	13′ 2⅛″	75	17′ 11⅝″	95	22′ 9⅛″
16	3′ 10″	36	8′ 7½″	56	13′ 5″	76	18′ 2½″	96	23′ 0″
17	4′ 0⅞″	37	8′ 10⅜″	57	13′ 7⅞″	77	18′ 5⅜″	97	23′ 2⅞″
18	4′ 3¾″	38	9′ 1¼″	58	13′ 10¾″	78	18′ 8¼″	98	23′ 5¾″
19	4′ 6⅝″	39	9′ 4⅛″	59	14′ 1⅝″	79	18′ 11⅛″	99	23′ 8⅝″
20	4′ 9½″	40	9′ 7″	60	14′ 4½″	80	19′ 2″	100	23′ 11½″

133.333

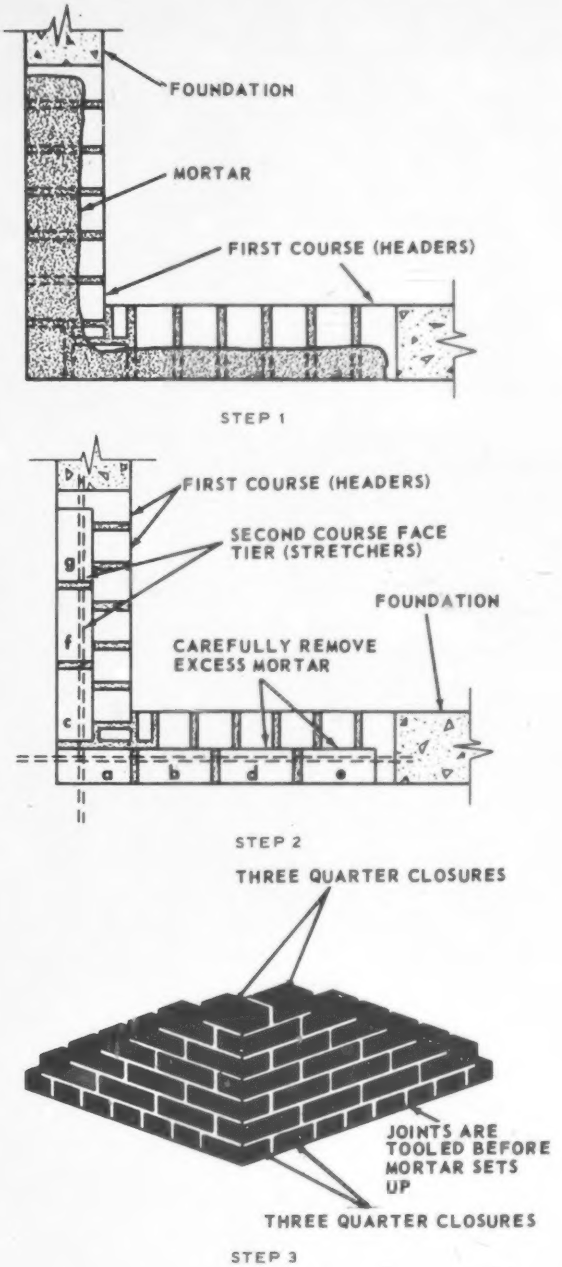

FOUNDATION
MORTAR
FIRST STEP IN LAYING CORNER
LAY MASON'S LEVEL IN THESE POSITIONS TO CHECK LEVEL
a
b
3/4 CLOSURES
SECOND STEP
c
e
d
a
b
f
1/4 CLOSURES
THIRD STEP
MORTAR
HEADERS
c
e
d
g
h
i
j
k
a
b
f
FOURTH STEP
p
o
n
m
l
c
HEADERS
FOUNDATION
e
d
g
h
i
j
k
a
b
f
FIFTH STEP

133.309

Figure 5-10. —First course of corner lead for 8-inch common bond brick wall.

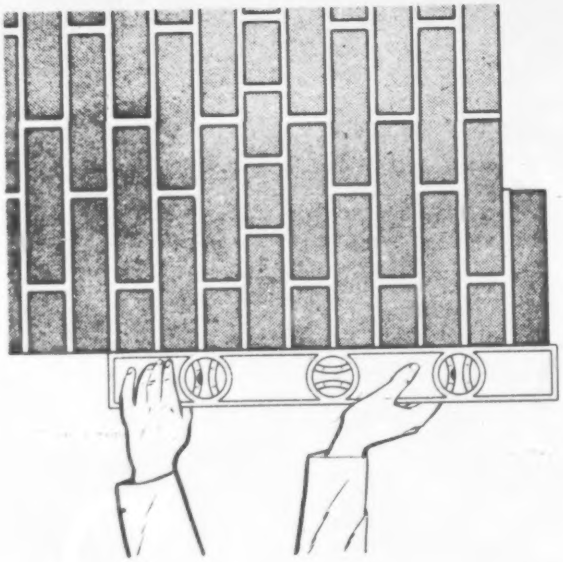
and 0.96 cu yds of sand to make a cu yd of 1:0.05:2 mortar. It takes 3 sacks of cement, 240 lb of lime, and 1 cu yd of sand to make a cu yd of 1:2:9 mortar. See figure 5-15 for the quantities of materials per cubic foot of mortar.

The norm for mortar mixing is about 4 cu yd per man-day. The norm for loading mortar and wheeling it 50 ft is about 8 cu yds per man-day.


FOUNDATION
MORTAR
FIRST COURSE (HEADERS)
STEP 1
FIRST COURSE (HEADERS)
SECOND COURSE FACE TIER (STRETCHERS)
FOUNDATION
CAREFULLY REMOVE EXCESS MORTAR
g
f
c
a
b
d
e
STEP 2
THREE QUARTER CLOSURES
JOINTS ARE TOOLED BEFORE MORTAR SETS UP
THREE QUARTER CLOSURES
STEP 3

133.310

Figure 5-11. –Second course of corner lead for 8-inch common bond brick wall.



133.311

Figure 5-12. –Plumbing a corner.

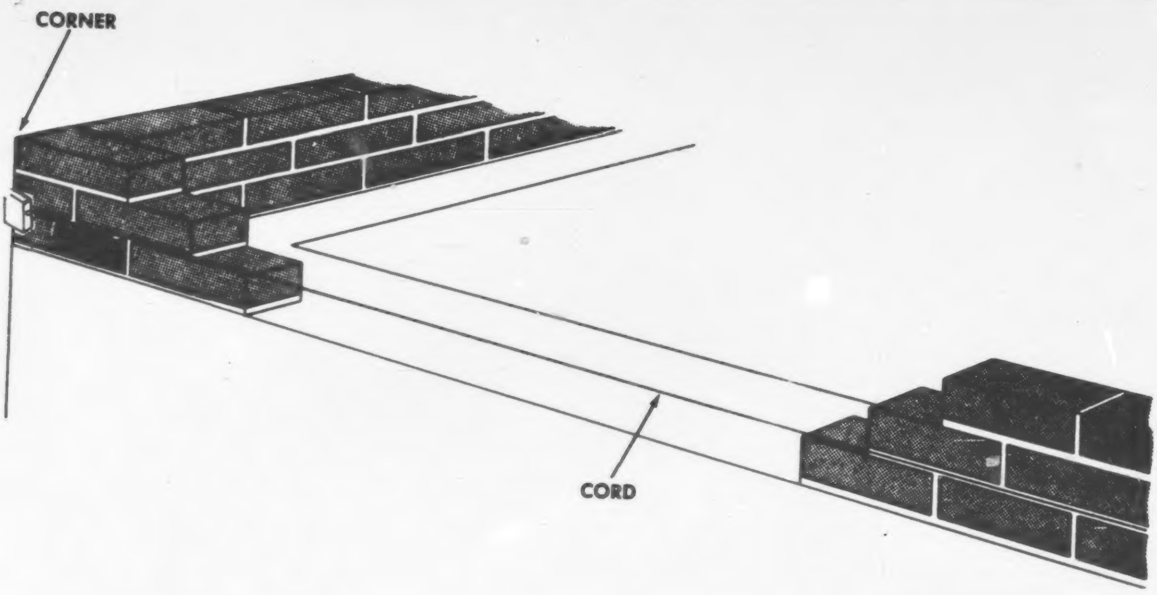
Twelve-Inch Common Bond Brick Wall

The 12-inch-thick common bond brick wall is laid out as shown in 3, figure 5-16. Note that the construction is similar to that for the 8-inch wall with the exception that a third tier of brick is used. The header course is laid (1, figure 5-16) first and the corner leads built. Two tiers of backing brick are required instead of one. The second course is shown in 2, figure 5-16 and the third course in 3, figure 5-16. Two header courses are required and they overlap as shown in 1, figure 5-16. A line should be used for the inside tier of backing brick for a 12-inch wall.

Protection of Brickwork and Use of a Trig

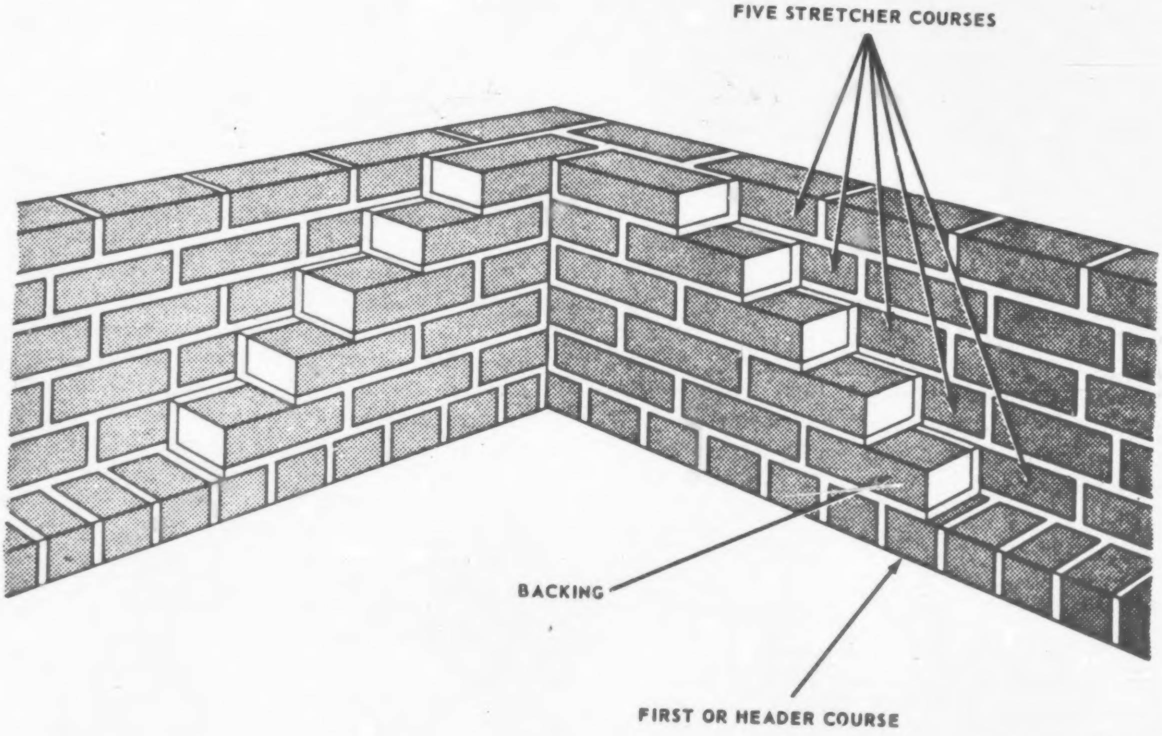
The tops of all brick walls should be protected each night from rain damage by placing boards or tarpaulins on top of the wall and setting loose bricks on them.

When a line is stretched on a long wall, a TRIG is used to prevent sagging and to keep it from being blown in or out from the face of the


CORNER
CORD

133.312

Figure 5-13. —Use of the line.


FIVE STRETCHER COURSES
BACKING
FIRST OR HEADER COURSE

133.313

Figure 5-14. —Backing brick at the corner—8-inch common bond brick wall.

Table 5-4. —Material and Labor Requirements for 1,000 Sq. Ft. of 1/2-Inch Joint Brick Wall

Character of construction	Thickness of wall (in.)	Number of bricks	Mortar (cu ft)	Approx time laborer (hrs)	Approx time, bricklayer (hrs)			
					Common Bond		Other bonds	
					Lime or cement-lime mortar	Cement mortar	Lime or cement-lime mortar	Cement mortar
Basement walls, solid: Outer 4-in. thickness laid with all joints filled. Other brick laid on full bed of mortar, touching end to end. Vertical space between 4-in. thicknesses filled with mortar Every fifth course headers	8	12, 706	195	97	73	93	------	------
	12	19, 252	314	149	110	140	------	------
	16	25, 797	433	200	129	159	------	------
Walls above grade, solid: Same construction, but vertical space between 4-in. thickness left open	8	12, 706	135	93	84	93	------	------
	12	19, 252	195	140	128	140	------	------
	16	25, 797	255	187	140	172	------	------
Walls above grade, solid: Outer 8-in. thickness laid with as many as possible vertical joints parallel with face of wall left open Other brick in thicker walls laid on full mortar bed but with brick touching end to end and vertical space between 4-in. thickness left open	8	12, 321	195	95	------	------	104	110
	12	18, 867	255	142	------	------	159	168
	16	25, 412	314	189	------	------	179	197
Walls above grade, solid: all joints filled with mortar	4	6, 161	76	46	62	68	------	------
	8	12, 321	195	95	90	99	104	110
	12	18, 482	314	144	135	148	156	164
	16	24, 642	433	192	152	179	179	197

117.182

wall by the wind. The trig consists of a short piece of line looped around the main line and fastened to the top edge of a brick that has been previously laid in proper position. A lead between the corner leads must be erected in order to place the trig brick in its proper location.

Window and Door Openings

If windows are to be installed in the wall, openings are left for them as the bricklaying proceeds. The height to the top of one full course should be exactly the height of the window sill. When the distance from the foundation to the bottom of the window sill is known, the number of courses that are required to bring the wall up to sill height can be determined. If the sill is to be 4 feet 4-1/4 inches above the foundation and 1/2-inch mortar joints are to be used, 19 courses will be required. (Each brick plus one mortar joint is 2-1/4 + 1/2 = 2-3/4 inches. One course is thus 2-3/4 inches high. Four feet 4-1/4 inches divided by 2-3/4 is 19, the number of courses required.)

With the brick laid up to sill height, the rowlock sill course is laid as shown in figure 5-17. The rowlock course is pitched downward. The slope is away from the window and the rowlock course normally takes up a vertical space equal to two courses of brick. The exterior

Table 5-5. —Material and Labor Requirements for Brickwork Footings and Piers

Construction	Number of bricks	Mortar (cu ft)	Approx time laborer (hrs)	Approximate time bricklayer (hrs)
Footings: quantities for 100 linear feet				
8-in. wall	2, 272	39	18	15
12-in. wall	2, 812	48	22	16
16-in. wall	4, 592	78	36	24
Piers: quantities for 10-ft height				
8 x 12-in. solid	124	2. 25	1. 00	1. 75
12 x 12-in. solid	185	3. 25	1. 50	2. 50
12 x 16-in. solid	247	4. 50	2. 00	3. 25
10 ¾-in. x 10 ¾-in. hollow brick laid on edge	113	1. 00	1. 25	2. 00

117.183

surface of the joints between the brick in the rowlock course must be carefully finished to make them watertight.

The window frame is placed on the rowlock sill as soon as the mortar has set. The window frame must be temporarily braced until the brickwork has been laid up to about one-third the height of the window frame. These braces are not removed for several days in order that the wall above the window frame will set properly. The remainder of the wall is then laid up so that the top of the brick in the course at the level of the top of the window frame is not more than 1/4 inch above the frame. Wall height can be adjusted through the addition or deletion of courses, expansion or reduction of the joint, or a combination of both. The corner leads should be laid up after the height of each course at the window is determined.

LINTELS are placed above windows and doors to carry the weight of the wall above them. They rest on the brick course that is level or approximately level with the frame head, and are firmly bedded in mortar at the sides. Any space between the window frame and the lintel is closed with blocking and weather-stripped with bituminous materials. The wall is then continued above the window after the lintel is placed.

The same procedure can be used for laying brick around a door opening as was used for laying brick around a window opening, including placement of the lintel. The arrangement at a door opening is given in figure 5-18. The frames of doors and windows are shimmed with wedges to square them. Then the expansion anchors or lead shields are installed to provide a means for securing the frames.

Lintels

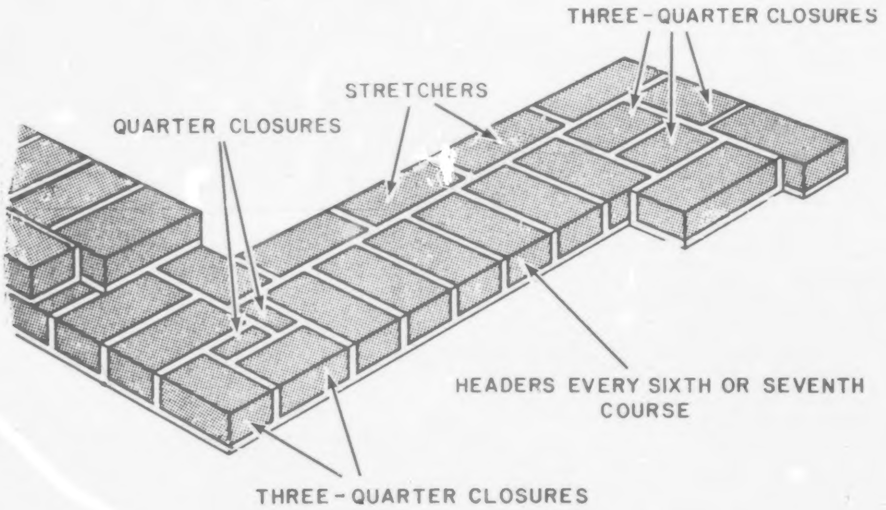
The brickwork above openings in walls must be supported by lintels. Lintels can be made of steel, precast reinforced concrete beams, or

MORTAR MIXES			QUANTITIES			
CEMENT SACK*	HYDRATED LIME OR LIME PUTTY CU.FT.	SAND** CU.FT.	MASONRY CEMENT SACK	PORTLAND CEMENT SACK	HYDRATED LIME OR LIME PUTTY CU. FT.	SAND** CU.FT.
1 MASONRY CEMENT	--	3	0.33	--	--	0.99
1 PORTLAND CEMENT	1	6	--	0.16	0.16	0.97
1 MASONRY CEMENT PLUS 1 PORTLAND CEMENT	--	6	0.16	0.16	--	0.97
1 PORTLAND CEMENT	1/4	3	--	0.29	0.07	0.86

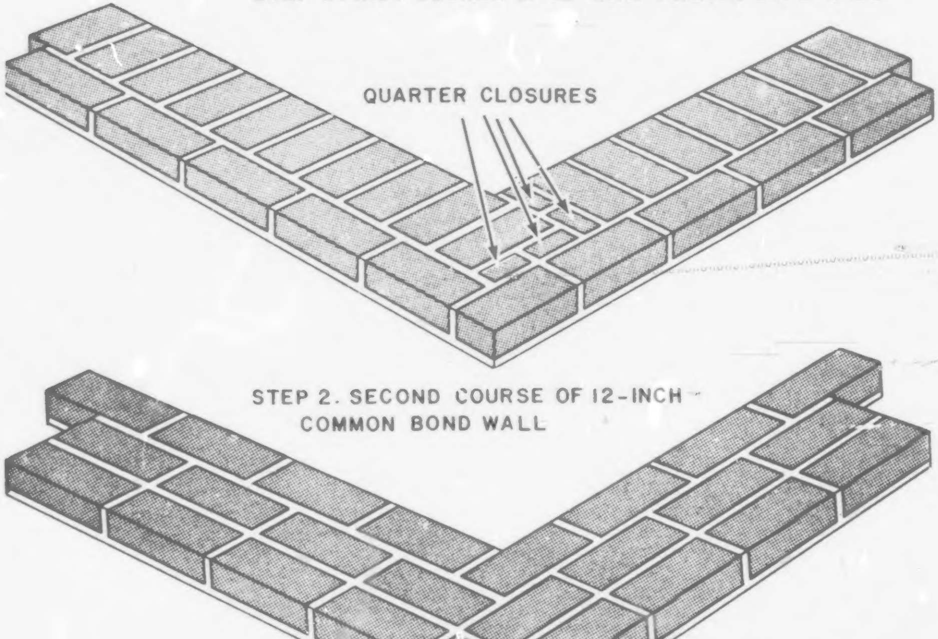
*1 SACK MASONRY CEMENT OR PORTLAND CEMENT = 1 CU. FT.
**SAND IN DAMP, LOOSE CONDITION.

117.357

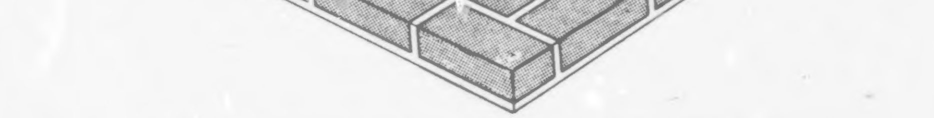
Figure 5-15. —Quantity of material per cubic foot of mortar.


THREE-QUARTER CLOSURES
STRETCHERS
QUARTER CLOSURES
HEADERS EVERY SIXTH OR SEVENTH COURSE
THREE-QUARTER CLOSURES

STEP 1. FIRST COURSE OF 12-INCH COMMON BOND WALL


QUARTER CLOSURES

STEP 2. SECOND COURSE OF 12-INCH COMMON BOND WALL



STEP 3. THIRD COURSE OF 12-INCH COMMON BOND WALL

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Figure 5-16. —Twelve-inch common bond wall.

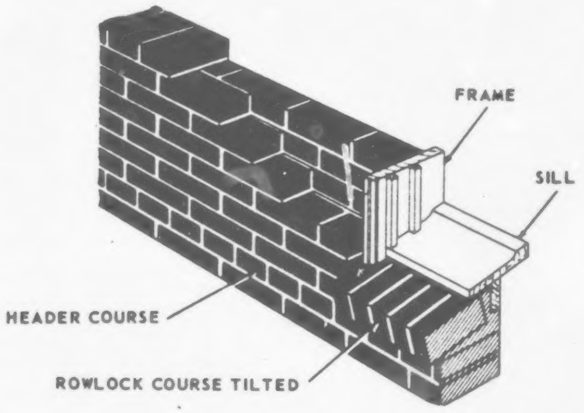

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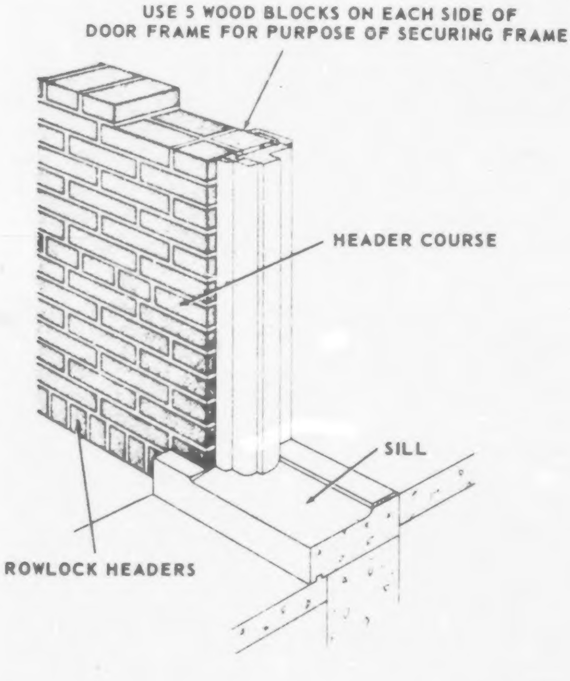
Figure 5-17. —Construction at a window opening.


USE 5 WOOD BLOCKS ON EACH SIDE OF DOOR FRAME FOR PURPOSE OF SECURING FRAME
HEADER COURSE
SILL
ROWLOCK HEADERS

133.315

Figure 5-18. —Construction at a door opening.

wood. The use of wood should be avoided as much as possible. If reinforced brick masonry is employed, the brick above the wall opening can be supported by the proper installation of steel reinforcing bars. This will be discussed later.

Figures 5-19 and 5-20 illustrate some of the methods of placing lintels for different wall thicknesses. The relative placement and position is determined both by wall thickness and the type of window being used.

Usually the size and type of lintels required are given on drawings for the structure. When not given, the size of double-angle lintels required for various width openings in an 8-inch and 12-inch wall can be selected from table 5-6. Wood lintels for various width openings are also given in table 5-6.

Installation of a lintel for an 8-inch wall is shown in figure 5-19. The thickness of the angle for a two-angle lintel should be 1/4 inch. This makes it possible for the two-angle legs that project up into the brick to fit exactly in the 1/2-inch joint between the face and backing-up ties of an 8-inch wall.

Corbeling

Corbeling consists of courses of brick set out beyond the face of the wall in order to form a self-supporting projection. This type of construction is shown in figure 5-21. The portion of a chimney that is exposed to the weather is frequently corbeled out and increased in thickness to improve its weathering resistance.

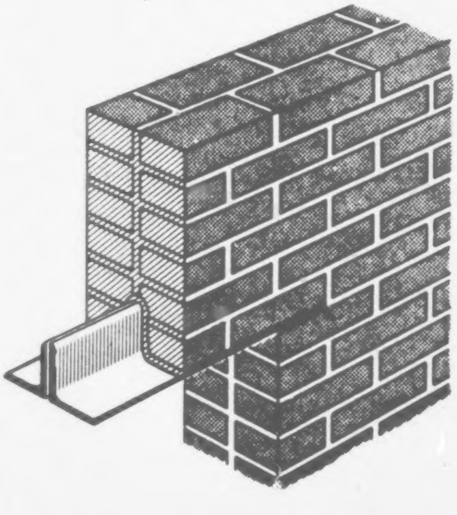


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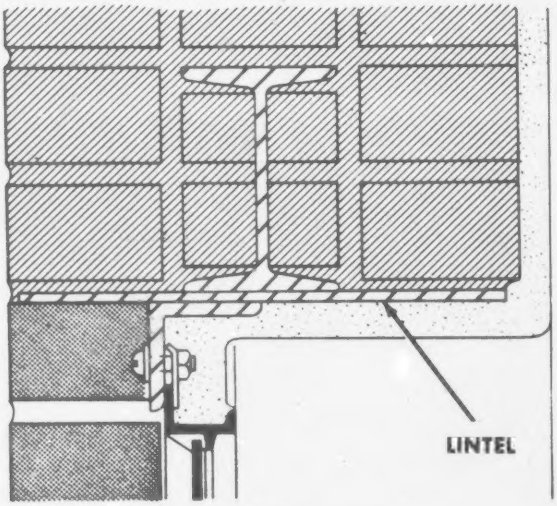
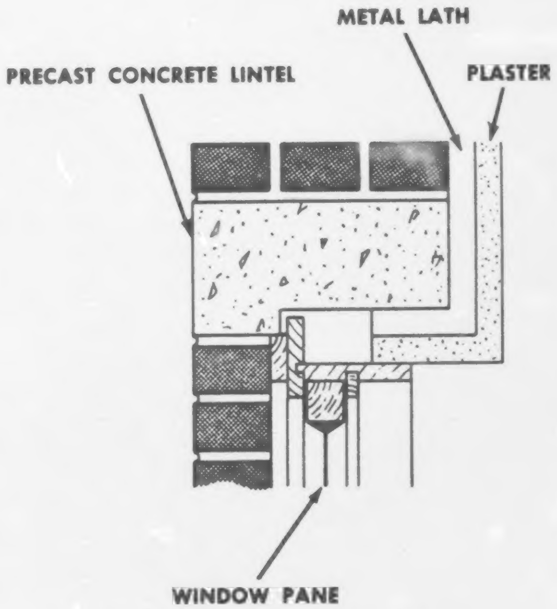
Figure 5-19. —Lintels for an 8-inch wall.



STEP 1 STEEL LINTEL



STEP 2 PRECAST CONCRETE LINTEL

45.486:.487

Figure 5-20. –Lintels for a 12-inch wall.

Headers should also be used as much as possible in corbeling. It is usually necessary to use various-sized bats. The first projecting course may be a stretcher course if necessary. No course should extend out more than 2 inches beyond the course below it and the total projection of the corbeling should not be more than the thickness of the wall.

Corbeling must be done carefully for the construction to have maximum strength. All mortar joints should be carefully made and completed filled with mortar. When the corbeled-out brick masonry is to withstand large loads, you should consult the design division of the operation department.

Special Types of Walls

Many different types of walls may be built of brick. The solid 8- and 12-inch walls in common bond are the ones usually used for solid wall construction in the United States. The most important of the hollow walls are the cavity wall and the rowlock type wall.

CAVITY WALLS provide a means of obtaining a watertight wall that may be plastered without the use of furring or lathing. From the outside they appear the same as solid walls without header course (figure 5-22). No headers are required because the two tiers of brick are held together by means of metal ties installed every sixth course and on 24-inch centers. To prevent waterflow to the inside tier, ties must be angled in a downward direction from the inside tier to the outside tier.

The 2-inch cavity between the two tiers of brick provides a space down which water that penetrates the outside tier may flow without passing through to the inside of the wall. The bottom of the cavity is above ground level and is drained by weep holes placed in the vertical joints between two bricks in the first course of the outer tier. These holes may be formed by leaving the mortar out of some of the vertical joints in the first course. The holes should be spaced at about 24-inch intervals. The air space also gives the wall better heat- and sound-insulating properties.

One type of ROWLOCK WALL is shown in figure 5-23. The face tier of this wall has the same appearance as a common bond wall with a full header course every seventh course. The backing tier is laid with the brick on edge. The face tier and backing tier are tied together by a

Table 5-6. —Lintel Sizes

WALL THICKNESS	SPAN						
	3 FEET		4 FEET* STEEL ANGLES	5 FEET* STEEL ANGLES	6 FEET* STEEL ANGLES	7 FEET* STEEL ANGLES	8 FEET* STEEL ANGLES
	STEEL ANGLES	WOOD					
8"	2-3 × 3 × ¼	2 × 8 2-2 × 4	2-3 × 3 × ¼	2-3 × 3 × ¼	2-3½ × 3½ × ¼	2-3½ × 3½ × ¼	2-3½ × 3½ × ¼
12"	2-3 × 3 × ¼	2 × 12 2-2 × 6	2-3 × 3 × ¼	2-3½ × 3½ × ¼	2-3½ × 3½ × ¼	2-4 × 4 × ¼	2-4 × 4 × 4¼

* Wood lintels should not be used for spans over 3 feet since they burn out in case of fire and allow the brick to fall.

133.334

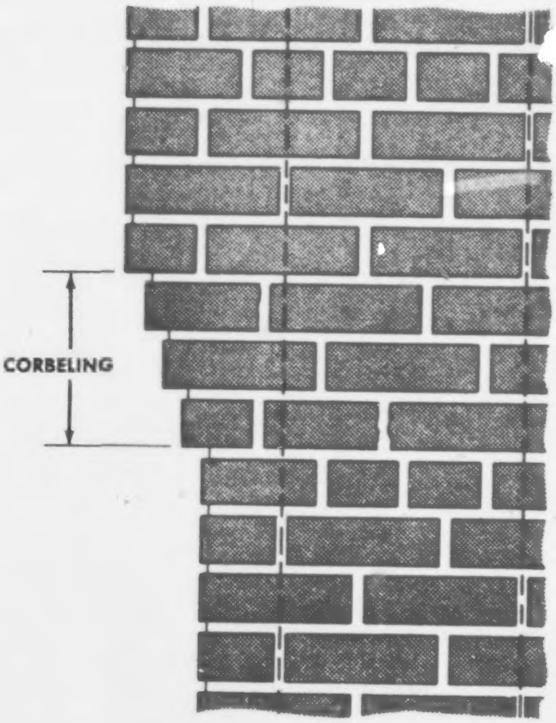


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Figure 5-21. —Corbeled brick wall.

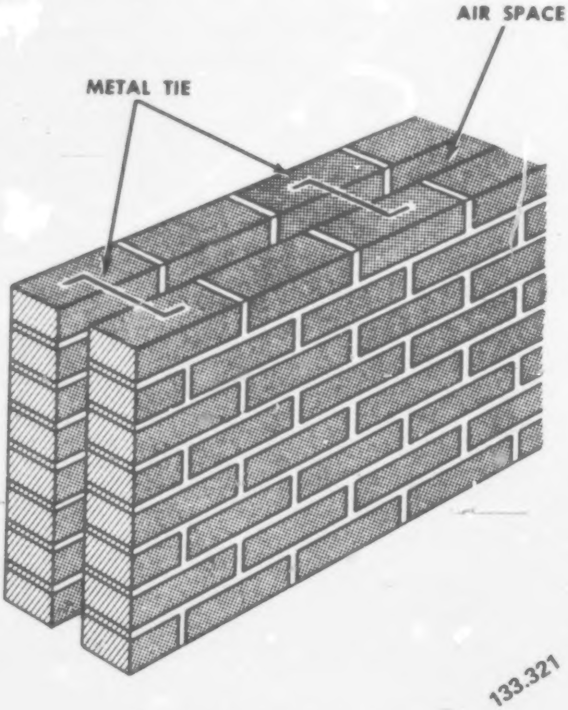

Figure 5-22. —Details for a cavity wall.

header course as shown. A 2-inch space is provided between the two tiers of brick, as for a cavity wall.

An all-rowlock wall is constructed with brick in the face and backing tier, both laid on edge. The header course would be installed at every fourth course: three rowlock courses to every header course. A rowlock wall is not as watertight as the cavity wall. Water is able to follow any crack present in the header course and pass through the wall to the inside surface.

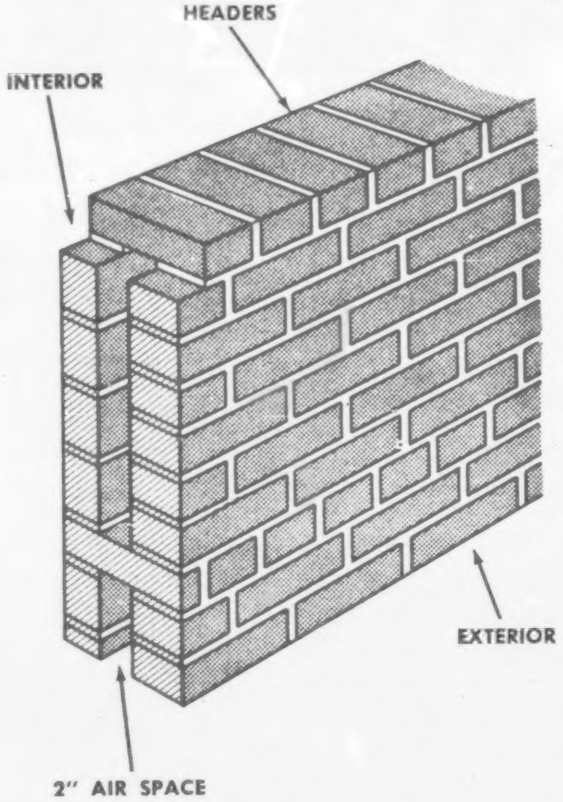

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Figure 5-23. –Details of a rowlock backwall.

PARTITION WALLS that carry very little load can be made using one tier of brick only. This produces a wall 4 inches thick. A wall of this thickness is laid up without headers.

Bricks are laid in cavity and partition walls according to the procedure given for making bed joints, head joints, cross joints, and closures. The line is used the same as for a common bond wall. Corner leads for these walls are erected first and the wall between is built up afterward.

REINFORCED BRICK MASONRY

Since brick masonry is strong in compression but weak in tension, reinforcing steel is used when tensile stresses are to be resisted. In this respect, brick masonry and concrete construction are identical. The reinforcing steel is placed in the horizontal or vertical mortar joints. Reinforced brick masonry may be used for beams, columns, walls, and footings in the same manner as reinforced concrete is used. Structures built of reinforced brick masonry have successfully resisted the effect of earthquake shocks intense enough to damage unreinforced brick structures severely. The design of reinforced brick masonry structures is similar to the design of reinforced concrete structures.

Brick used for reinforced brick masonry is the same as that used for ordinary brick masonry. It should, however, have a compressive strength of at least 2,500 pounds per square inch.

The reinforcing steel is the same as the steel used to reinforce concrete and it is stored and fabricated in the same way. Hard-grade steel should not be used except in emergencies because many sharp bends are required in this type of construction.

Type N mortar is used because of its high strength.

Wire for tying reinforcing steel should be 16-gage soft annealed iron wire.

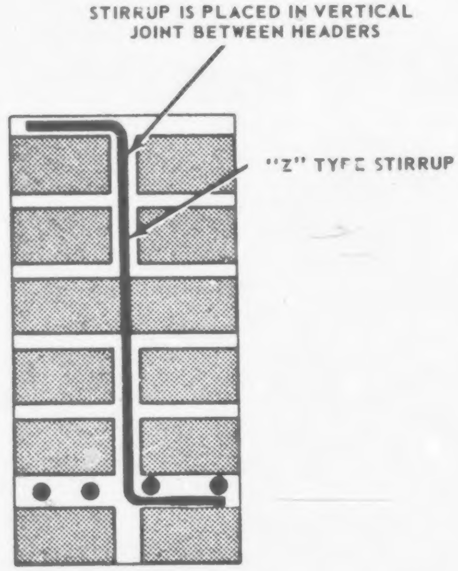
Construction Methods for Reinforced Brick Masonry

Bricklaying is the same as for normal brick masonry. Mortar joint thickness is 1/8 inch more than the diameter of the steel bar used for reinforcing. This will allow 1/16 inch of mortar between the surface of the brick and the bar. When large steel bars are used, the thickness of the mortar joint will exceed 1/2 inch.

All reinforcing steel must be firmly embedded in mortar.

Horizontal bars are laid in a bed of mortar and pushed down until in position. More mortar is spread on top of the rods and smoothed out until a bed joint of the proper thickness can be made. The next course of brick is then laid in this mortar bed according to the procedure outlined for laying brick without reinforcing steel.

Stirrups for most reinforced brick beams must be of the shape shown in figure 5-24 in order to place them in the mortar joints. The lower leg is placed under the horizontal bars and in contact



133.323
Figure 5-24. —Reinforced brick masonry beam.

with them. Note that this may require a thicker joint at this point.

Vertical bars are placed in the vertical mortar joints. They are held in position by wood templets in which holes have been drilled at the proper bar spacing or by wiring to a horizontal bar. The brick is laid up around the vertical bars.

Horizontal and vertical bars need not be wired together as was recommended for reinforcing steel in concrete walls.

The minimum center-to-center spacing between parallel bars is 1-1/2 times the bar diameter.

Reinforced brick beams require form work for the same reason that reinforced concrete beams need form work. The form will consist only of a support for the bottom of the beam. No side form work is required. The form for the bottom is the same and is supported in the same way as recommended for concrete beams. No form work is required for walls, columns, or footings.

Where the beam joins a wall or another beam, the form should be cut 1/4 inch short and the gap filled with mortar to allow for swelling of the lumber and to permit easy removal of the forms. (At least 10 days should elapse before the bottom form work for beams is removed.)

Reinforced Brick Masonry Beams

The width and depth of beams depend upon brick dimensions, thickness of the mortar joints, and the load that the beam is required to support. Beam widths are usually the same as the wall thicknesses; that is, 4, 8, 12, and 16 inches. The depth should not exceed about three times the width.

The first course of brick is laid on the form with full head joints but without a bed joint (figure 5-24).

A bed of mortar about 1/8 inch thicker than the diameter of the horizontal reinforcing bars is spread on the first course of brick and the bars embedded in it as already described.

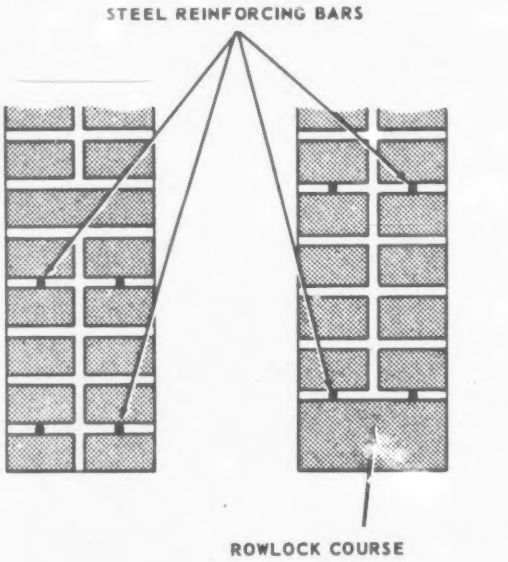
If stirrups are required, the leg of the stirrup is slipped under the horizontal bars as shown in figure 5-24. Care must be taken to get the stirrup in the center of the vertical mortar joint in which it is to be placed.

After the stirrups and the horizontal bars are in the proper position, spread additional mortar on the bed joint if necessary, and smooth the surface of the mortar. The mortar bed is now ready for the remaining courses which are laid in the usual way.

All of the brick in one course are laid before any brick in the next course are placed. This is necessary to ensure a continuous bond between the mortar and steel bars. It is frequently necessary to have three or four Builders working on one beam in order to get the bed joint mortar for the entire course spread, reinforcing steel placed, and brick laid before the mortar sets up.

The proper placement of reinforcing steel in the brick wall above a window or door opening will serve the purpose of a lintel.

The steel bars should be 3/8 inch in diameter or less if it is necessary to maintain a 1/2 inch thick mortar joint. The bars should extend 15 inches into the brick wall on each side of the opening and should be placed in the first mortar joint above the opening and also in the fourth joint above the opening (figure 5-25). The lintel acts as a beam and needs a bottom form. The



133.324

Figure 5-25. —Reinforced brick masonry lintels.

number and size bars required for different width wall openings are as follows:

Width of wall opening in feet	Number and size of bars
6	2-1/4-inch diameter bars
9	3-1/4-inch diameter bars
12	3-3/8-inch diameter bars

Reinforced Brick Masonry Columns and Walls

The load-carrying capacity of brick columns is increased when they are reinforced with steel bars. There should be at least 1-1/2 inches of mortar or brick covering the reinforcing bars, and these bars should be held in place with 3/8-inch diameter steel hoops or ties as shown in figure 5-26. When possible, the hoops or ties should be circular rather than rectangular or square. The ends of the hoop or tie should be lap-welded together or bent around a reinforcing bar. Hoops should be installed at every course of brick.

After the footings are completed, the column reinforcing steel is tied to the dowels projecting from the footing. The required number of hoops is then slipped over the longitudinal reinforcing bars and temporarily fastened to these bars some distance above the level at which brick are being laid, but within reach of the Builder laying brick. It is not necessary for the hoops to be held in position by wiring them to the longitudinal reinforcing. The tops of the longitudinal reinforcing bars are held in position by means of a wood templet or by securely tying them to a hoop placed near the top of the column.

The brick are laid as described previously. The hoops are placed in a full bed of mortar and the mortar smoothed out before the next course of brick is laid. Brick bats may be used in the core of the column or where it is inconvenient or impossible to use full-size brick. After all the brick in a course are laid, the core and all remaining space around the reinforcing bars is filled with mortar. Any bats required are then pushed into the mortar until completely embedded. The next mortar bed is now spread and the process repeated.

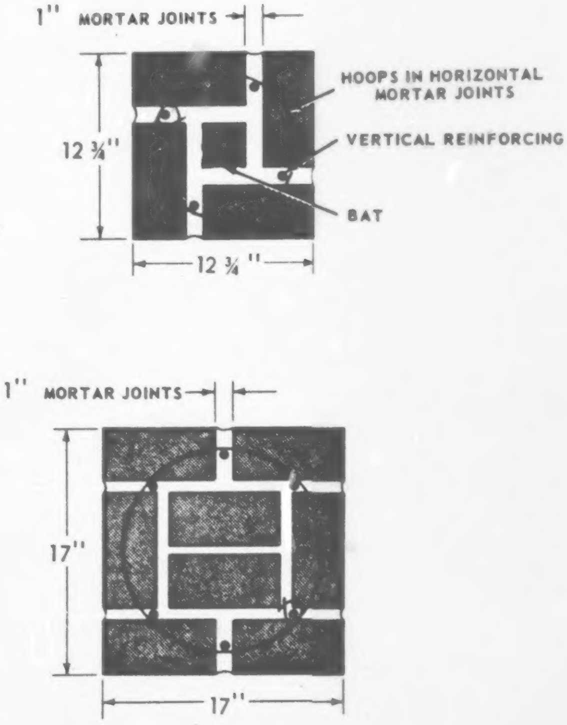


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Figure 5-26. —Reinforced brick masonry columns.

Reinforcing steel for walls consists of both horizontal and vertical bars and is placed as discussed previously. The vertical bars are wired to the dowels projecting up from the footing below and are placed in the mortar joint between tiers of brick. As the bricks are laid, all space around the bars is filled with mortar. Otherwise, the wall is constructed as specified.

In the construction of corner leads, bars should be placed in the corner as shown in figure 5-27. The extension is 15 inches and the bar size should be the same as that used for horizontal bars in the rest of the wall. The horizontal bars in the remainder of the wall lap these corner bars by the same 15 inches. As for beams, all the brick in one course between corner leads are laid before any other brick are laid. This is necessary since the entire reinforcing bar must be embedded in mortar at the same time.

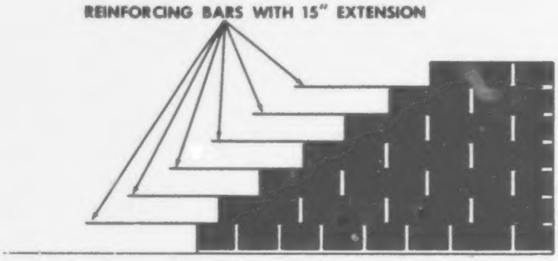

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Figure 5-27. —Corner lead for reinforced brick masonry wall.

CHAPTER 6

PLASTERING, WALL TILES, AND ACOUSTICAL CEILINGS

Plastering and tile setting, like bricklaying, are skills currently being taught in a special Builder "C" school. As a BU 1 or C, although not required to be proficient in the performance of these skills, you are responsible for the supervision of qualified personnel engaged in their performance. With this in mind, the following discussion is designed to acquaint you with the principles of installing gypsum lath, plaster base and finish coats, and ceramic and plastic wall tiles. Information is also provided on the principles of installing suspended acoustical ceiling systems.

PLASTER

Plaster, like concrete, is a construction material that is applied in a plastic condition and hardens in place as a result of hydration. The active ingredient in plaster is a cementitious material, or BINDER. The binders most commonly used are GYPSUM, LIME, and PORTLAND CEMENT. The inert ingredients are aggregate and water.

GYPSUM PLASTER

Gypsum plaster is limited entirely to interior finish work, whereas lime and portland cement plaster may be used for both interior and exterior finish work. Most plastering done by the SEABEES is interior finish work using gypsum plaster. For this reason, the following discussion will deal with the materials and procedures common to the installation of gypsum plaster. The basic ingredients in a gypsum plaster mixture are water, aggregate, and gypsum.

Water

The mixing water in plaster performs two functions. First, it transforms the dry ingredients into a plastic, workable mass; second, it combines mechanically and/or chemically with the binder to induce hardening. As is the case with concrete, there is a maximum quantity of water per unit of binder required for complete hydration, and an excess over this amount reduces the plaster strength below the maximum attainable.

However, in all plaster mixing more water is added than is necessary for complete hydration of the binder; the excess is necessary to bring the mix to workable consistency. The amount that must be added for workability depends on the character and age of the binder, the method of application, the drying conditions, and the tendency of the base to absorb water.

As a general rule, only the amount of water required to attain workability is added to a mix, and no more. The water should be clean and fresh, and it must contain no dissolved chemicals which might accelerate or retard the set. Water previously used to wash plastering tools should never be used for mixing plaster; such water may contain particles of set plaster which may accelerate setting. Stagnant water should be avoided, because such water may contain organic material which may retard setting and possibly cause staining.

Aggregate

The aggregate most commonly used in plaster is sand because it is relatively cheap and readily available. However, the use of lightweight aggregates such as vermiculite and perlite has become increasingly popular, primarily because they greatly reduce the weight of the plaster mix and tend to increase its acoustic and insulating qualities.

SAND.–Sand for plaster, like sand for concrete, must be free of more than a specified minimum of organic impurities and harmful chemicals. Certain tests for these impurities and chemicals are conducted by qualified personnel.

Proper aggregate gradation influences plaster strength and workability, and likewise has an effect on the tendency of the material to shrink or expand while setting. For sand intended for use in gypsum plaster, recommended gradation is as follows:

	Percentage Retained by Weight	
Sieve Size	Maximum	Minimum
No. 4	0	–
No. 8	5	0
No. 16	30	5
No. 30	65	30
No. 50	95	65
No. 100	100	90

Plaster strength is reduced if excessive fine aggregate material is present in a mix. The greater quantity of mixing water required raises the water:cement ratio, thereby reducing the dry set density. The cementitious material becomes overextended, because it must coat a relatively larger overall aggregate surface.

An excess of coarse adversely affects workability; the mix becomes "harsh working" and difficult to apply.

Plaster shrinkage during drying may be caused by an excess of either fine or coarse. Because an excess of fine increases the aggregate total surface area, a larger quantity of binder paste is needed to coat all particles. The mix becomes too rich in cementitious material, and it is the cementitious material which is unstable after application. The end-effect is much the same if there is too much coarse; in this case, there is not enough fine to fill the voids between coarse particles, and more cementitious material must be used to fill these voids. Again the result is a rich and relatively unstable material.

VERMICULITE.–VERMICULITE is a MICACEOUS mineral– meaning a mineral in which each particle is LAMINATED, or made up of adjoining layers. When vermiculite particles are exposed to intense heat, steam forms between the layers so as to force them apart; this causes each particle to increase from 6 to 20 times in volume. The expanded material is soft and pliable, with a color varying between silver and gold.

For ordinary plaster work, vermiculite is used only with gypsum plaster–therefore, in general, only for interior plastering. For acoustical plaster, vermiculite is combined with a special acoustical binder.

Expanded vermiculite is manufactured in five types (I, II, III, IV, and V) according to particle size. Only type III is used in plastering. It is the lightest of the standard plaster aggregates, weighing only from 6 to 10 lb. per cu ft. The approximate dry weight of a cu ft of 1:2 gypsum-vermiculite plaster is 50 to 55 lb; the dry weight of a cu ft of comparable sanded plaster is 104 to 120 lb.

For gypsum-vermiculite plaster the following gradation for the vermiculite is recommended:

	Percentage Retained by Volume	
Sieve Size	Maximum	Minimum
No. 4	0	–
No. 8	10	0
No. 16	75	40
No. 30	95	65
No. 50	98	75
No. 100	100	90

PERLITE.–Raw perlite is a volcanic glass which, when flash-roasted, expands to form frothy particles of irregular shape that contain countless minute air cells and weighs only 7.5 to 15 lb per cu ft. Perlite ore is crushed and then heated to high temperature; as the particles soften, combined water turns to steam. This causes the particles to "pop," forming a frothy mass of glass bubbles 4 to 20 times the volume of the raw particle. The process is called EXPANDING; the color of expanded perlite ranges from pearly white to grayish white.

Perlite is used with calcined gypsum or portland cement for interior plastering; it is also used with special binders for acoustical plaster. The approximate dry weight of a cu ft of 1:2 gypsum-perlite plaster is 50 to 55 lb, or about half the weight of a cu ft of sand-plaster.

For gypsum-perlite plaster the recommended gradation for the perlite is as follows:

	Percentage Retained by Volume	
Sieve Size	Maximum	Minimum
No. 4	0	–
No. 8	5	0
No. 16	60	10
No. 30	95	45
No. 50	98	75
No. 100	100	88

Gypsum

Gypsum is a naturally occurring sedimentary gray, white, or pink rock. The natural rock is crushed and then heated to high temperature, a process (known as CALCINING) which drives off about three-quarters of the WATER OF CRYSTALLIZATION which forms about 20 percent by weight of the rock in a natural state. The calcined material is then ground to a fine powder, to which certain ADDITIVES are added to control set, stabilization, and other physical or chemical characteristics.

The removal of water of crystallization from natural gypsum is a DEHYDRATION process. In the course of setting, mixing water (water of hydration) added to the mix REHYDRATES with the gypsum, thus causing RECRYSTALLIZATION. Recrystallization causes the plaster to harden.

PLASTER BASES

For plastering there must be a continuous surface to which the plaster can be applied and to which it will cling; such a surface is called a plaster BASE. A continuous concrete or masonry surface may serve as a base without the necessity for further treatment.

For plaster planes such as those defined by the inner edges of studs or the lower edges of joists, however, base material must be installed to form a continuous surface which will span the spaces between the structural members. Material of this kind is called LATH. Lath formerly consisted of thin wooden strips which were nailed at right angles to the studs or joists. Narrow openings were left between adjacent laths, through which the plaster penetrated to form a KEY which bonded the plaster to the lath. In modern plastering, wooden lath has been almost entirely superseded by GYPSUM lath.

GYPSUM LATH

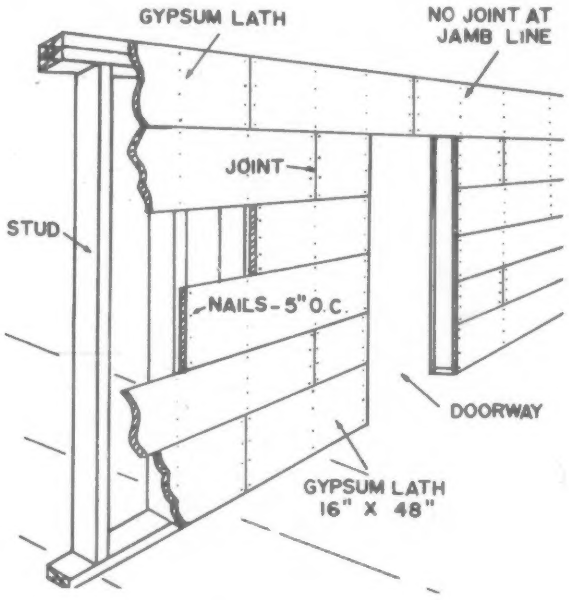
Gypsum lath is the most popular plaster base in use today. Compared to wood lath, it provides a better surface for bonding, is generally fireproof, has greater insulating qualities, and adds more rigidity to the structural framework.

Gypsum lath is made by sandwiching a core of gypsum plaster between two sheets of a fibrous, absorbent paper. For PLAIN (nonperforated) gypsum lath, bond is effected by absorption or suction of the face of the lath. This absorption draws in some of the cementitious material in the plaster. As the plaster sets, particles of this absorbed material interlock with nonabsorbed particles in the plaster. For PERFORATED (punched with 3/4-in. holes 4 in. apart) gypsum plaster, suction bond is supplemented by keys formed by plaster which penetrates the holes.

Standard sheet size for gypsum lath is 16 in. x 48 in., except in the western U.S., where it is 16-1/4 in. x 47 in. LONG LENGTH gypsum lath comes 16 or 24 in. wide and any length up to 12 ft. Available thicknesses are 3/8 in. and 1/2 in. INSULATING gypsum lath has aluminum foil bonded to the back of the sheet; this material provides thermal insulation and also serves as a vapor barrier.

Gypsum lath is nailed to studs, joists, or furring strips with 1 1/8-in. to 1-1/4 in.

flatheaded GYPSUM LATH NAILS spaced 5 inches on center. Standard size gypsum lath should be applied with the longer side in a horizontal position taking care to stagger the joints as shown in figure 6-1. In order to prevent buckling, nailing should start on studs or furring strips that fall near the center of the board and then work toward the ends taking care to stay at least 1/2 inch from the edge to prevent breaking.

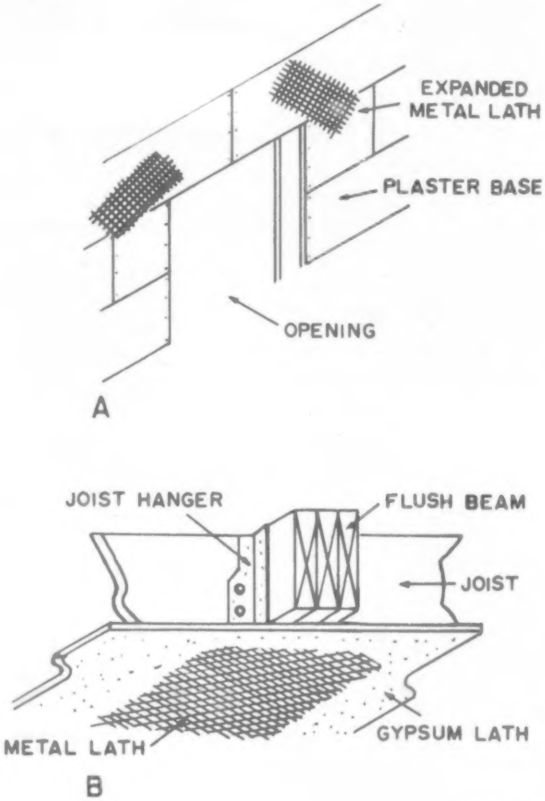


117.358
Figure 6-1. —Application of gypsum lath.

Special attention should be given to door and window heads. At these places, the lathing should be worked out in such a way that a joint will not occur at either edge of the opening. Such places are weak spots on any wall and require reinforcement.

Joint Reinforcement

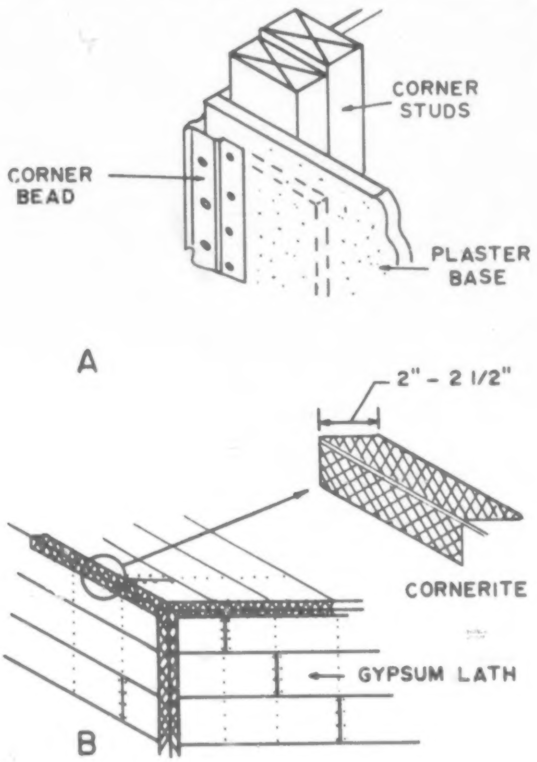
To prevent cracking of the plaster finish, 3-inch wide expanded metal lath (normally referred to as strip-lath) is nailed over the gypsum lath at the angles formed around the door and window openings (view A, fig. 6-2) and under flush beams (view B, fig. 6-2). Corner beads of expanded metal lath or of perforated metal should be installed on all external corners as shown in view A of figure 6-3. They should be applied plumb and level. The bead acts as a leveling edge or GROUND when walls are plastered and reinforce the corner against mechanical damage. To minimize plaster cracks, inside corners at the juncture of walls and ceilings should also be reinforced. Metal lath or wire fabric (normally referred to as cornerite) is tacked lightly in place in these areas. (See view B, figure 6-3.)



117.359
Figure 6-2. —Metal lath used to minimize cracking: (A) At door and window openings; (B) Under flush beams.

Grounds and Screeds

Plaster GROUNDS are strips of wood or metal used as guides or strike-off edges when



117.360
Figure 6-3. —Reinforcing of plaster at corners: (A) Outside; (B) Inside.

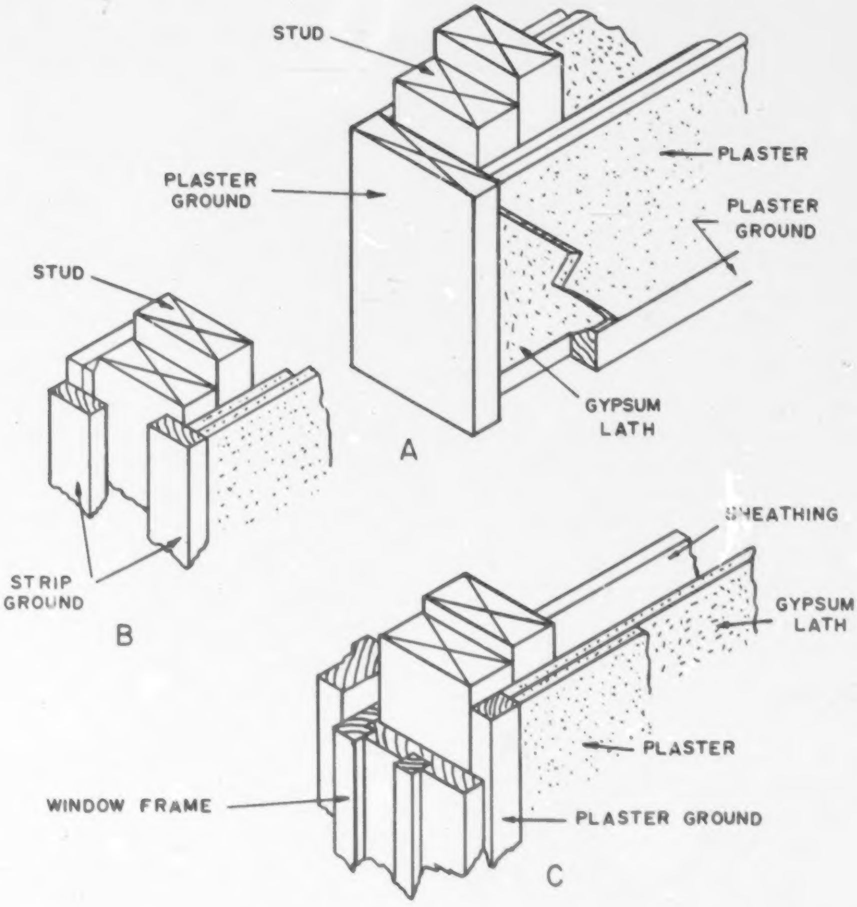
plastering and are located around window and door openings and at the base of the walls. The primary purpose of grounds is to ensure that plaster will be applied to the correct thickness in locations where variations in thickness would be especially noticeable. Grounds around interior door openings are often full width pieces nailed to the sides over the studs and to the underside of the header. They are 5 1/4 inches in width, which coincides with standard jamb widths for interior walls with a plaster finish. (See view A, fig. 6-4.) They are removed after the plaster has dried.

Narrow strip grounds might also be used around these interior openings as shown in view B of figure 6-4. In windows and exterior door openings, the frames are normally in place before plaster is applied. Thus, the inside edges of the side and head jamb can, and often do, serve as grounds; however, it is not advisable to plaster directly to the wood in such cases. Contact between the dimensionally unstable wood and the more stable plaster produces differential movement (additionally complicated by the shock of opening and closing a door or window) which may damage plaster edges. If casing beads are not used, the plaster should be struck away from the wooden jamb after the surface has been leveled. The edge of the window sill might also be used as a ground, or a narrow 7/8-inch-thick ground strip is nailed to the edge of the 2 by 4 sill. Narrow 7/8-by 1-inch grounds might also be used around windows and door openings. (See view C, figure 6-4.) These are normally left in place and are covered by the casing. A similar narrow ground is used at the bottom of the wall to control plaster thickness and to provide an even surface for the baseboard and moulding (view A, fig. 6-4). These strips are also left in place after plaster has been applied.

PLASTER SCREEDS are grounds consisting of narrow strips of plaster 4 to 6 in. wide, placed at intervals on large wall or ceiling areas. DOTS of plaster of the proper thickness are placed first, then connected by bands of the proper thickness. The spaces between the bands are then filled in, after the bands (that is, the screeds) have hardened enough to support the plastering straightedge.

PLASTER MIXTURES

Much of the plaster used by the SEABEES comes ready-mixed, requiring only the addition of enough water on the job to attain minimum required workability. For job mixing, tables are available which give recommended ingredient proportions for gypsum, lime, and portland cement plaster for base coats on lath or on various types of concrete or masonry surfaces, and for finish coats of various types. This text can present recommended proportions for only the more common types of gypsum plastering situations. In the following sections, one part of cementitious material means 100 lb or one sack of gypsum. One part of aggregate means 100 lb sand or 1 cu ft vermiculite or perlite.



117.361

Figure 6-4. —Plaster grounds: (A) At doorway and floor; (B) Strip ground at doorway; (C) Ground at window.

BASE COAT PROPORTIONS

TWO-COAT plaster work consists of a single base coat and a finish coat. THREE-COAT work consists of two base coats (the first called the SCRATCH coat, the second, the BROWN coat) and a FINISH coat.

Portland cement plaster cannot be applied to a gypsum base. Lime plaster can in theory, but in practice only gypsum plaster is applied to gypsum lath as a base coat. For two-coat work on gypsum lath, the recommended base coat proportions for gypsum plaster are 1:2.5.

For three-coat work on gypsum lath, the recommended base coat proportions for gypsum plaster are: scratch coat 1:2, brown coat 1:3, or both coats 1:2.5.

There are four common types of gypsum basecoat plasters, as follows:

GYPSUM PLASTER is a basecoat plaster which requires the addition of an aggregate and water to produce working qualities. It is supplied as either Fibered or Unfibered and is designed for interior use over all accepted plaster bases. Gypsum plasters are formulated for machine spray application and for use with light-weight aggregates, when so specified.

GYPSUM READY-MIXED plaster consists of gypsum and ordinary mineral aggregate; at the job it requires addition of only the water.

GYPSUM WOOD FIBERED plaster is a gypsum basecoat plaster containing fine particles of selected wood fiber. It normally requires the addition of water only; however, when used over masonry or for the brown coat in 3 coat work over lath bases it can be mixed with sand in a proportion not to exceed 1:1 weight. Wood Fibered Plaster can be applied to all standard lath and masonry plaster bases and is ideally suited for alteration and repair work. It is also highly recommended for scratch coat application on metal lath for maximum crack resistance.

GYPSUM CONCRETE BOND is a specially formulated gypsum basecoat bonding plaster that provides a strong bond to properly roughened interior concrete surfaces. Water only is added in mixing. Concrete Bond Plaster has special bonding properties for application to monolithic concrete which is sufficiently roughened for mechanical key.

FINISH COAT PROPORTIONS

A lime finish may be applied over a lime gypsum, or portland cement base coat; other finishes, however, should be applied only to base coats containing the same cementitious material. A gypsum-vermiculite finish should be applied only to a gypsum-vermiculite base coat.

Finish coat proportions vary according to whether the surface is to be finished with a TROWEL or with a FLOAT. These tools are described later. The trowel attains a smooth finish; the float attains a finish of a desired texture.

For a trowel-finish coat using gypsum plaster, the recommended proportions are 200 lb hydrated lime or 5 cu ft lime putty to 100 lb gypsum gauging plaster.

For a trowel-finish coat using lime-Keene's cement plaster the recommended proportions are, for a medium-hard finish, 50 lb hydrated lime or 100 lb lime putty to 100 lb Keene's cement. For a hard finish, the recommended proportions are 25 lb hydrated lime or 50 lb lime putty to 100 lb Keene's cement.

For a trowel-finish coat using gypsum gauging or gypsum neat plaster and vermiculite aggregate the recommended proportions are 1 cu ft vermiculite to 100 lb Keene's cement.

Recommended proportions for various types of float-finish coats are as follows:

Lime putty 2: Keene's cement 1.5: sand 4.5, by volume
Hydrated lime 1: gypsum gauging plaster 1.5: sand 2.3, by weight
Gypsum neat plaster 1: sand 2, by weight

There are five common types of gypsum finish coat plasters, as follows:

READY-MIX GYPSUM FINISH plasters are designed for use over gypsum plaster basecoats. They consist of finely ground calcined gypsum, some with and others without aggregate. At the job they require addition of water only.

GYPSUM ACOUSTICAL plasters are designed to reduce sound reverberation.

GYPSUM GAUGING plasters contain LIME PUTTY, the inclusion of which provides certain setting properties, increases dimensional stability during drying, and provides initial surface hardness. Gauging plasters are obtainable as SLOW-SET, QUICK-SET, and SPECIAL HIGH STRENGTH.

GYPSUM MOLDING plaster is used primarily in casting and ornamental plaster work. It is available neat (that is, without admixtures) or with lime. As with portland cement mortar, the addition of lime to a plaster mix makes the mix more "buttery."

KEENE'S CEMENT is a fine, high density plaster capable of creating a highly polished surface. It is customarily used with lime putty, and with fine sand which provides crack-resistance.

PLASTER QUANTITY ESTIMATES

The total volume of plaster required for a job is, of course, the product of the thickness of the plaster times the net area to be covered. Plaster specifications state a minimum thickness, which the plasterer must not go under, and which he should likewise exceed as little as possible, because the tendency of cracking increases with thickness. Specified minimum thickness for gypsum plaster on metal lath, wire lath, masonry/concrete walls and masonry ceilings is usually 5/8 inch; on gypsum lath it is 1/2 inch.

The yield for a given quantity of plaster ingredients, like the yield for a given quantity of concrete ingredients, amounts to the sum of the ABSOLUTE VOLUMES of the ingredients. The absolute volumes of typical plaster ingredients are as follows:

100 lb gypsum	0.69 cu ft
100 lb sand	0.61 cu ft
1 cu ft lime putty	0.26 cu ft
1 cu ft perlite	0.17 cu ft
1 cu ft vermiculite	0.12 cu ft

This list indicates that (for example) 100 lb of gypsum, which has a "loose" volume of 1 cu ft, has an absolute volume (that is, a solid or exclusive-of-air-voids volume) of only 0.69 cu ft. Therefore, 100 lb of gypsum contributes a volume of only 0.69 cu ft to a plaster mix.

The absolute volume of the last ingredient–the water–is the same as its "loose" volume: 0.13 cu ft per gallon.

Determining Yield

Suppose now that you want to determine the yield of a plaster mix containing 1 part of gypsum plaster to 2.5 parts of sand. One part of gypsum plaster is 100 lb, with an absolute volume of 0.69 cu ft. Two and one-half parts of sand means 250 lb of sand. Sand has an absolute volume of 0.61 cu ft per 100 lb; therefore, the absolute volume of the sand is 2.5 x 0.61, or 1.52 cu ft.

The water will contribute 0.13 cu ft of volume to the mix for every gallon of water added. For approximate yield calculations, you can assume that 8 gals of water will be used for every 100 lb of cementitious material. There are 100 lb of gypsum plaster in question here, which means 8 gals of water. The water volume, then, will be 8 x 0.13, or 1.04 cu ft.

The yield for a 1-sack batch of this mix will be the sum of the absolute volumes, or 0.69 cu ft (for the gypsum) plus 1.52 cu ft (for the sand) plus 1.04 cu ft (for the water), or 3.25 cu ft.

Estimating Ingredient Quantities

Suppose that the plastering job is a wall with a net area of 160 sq ft, with a specified total plaster thickness of 5/8 in. and a finish coat thickness of 1/16 in. You are doing two-coat work (only a single base coat), and you want to estimate ingredient quantities for the base coat. The thickness of the base coat will be 5/8 in. minus 1/16 in., or 9/16 in., which equals about 0.046 ft. The volume of plaster required for the base coat, then, will be 160 x 0.046, or about 7.36 cu ft.

The yield for a 1-sack batch is 3.25 cu ft; therefore, the job calls for a batch with sacks to the number indicated by the value of x in the equation 1:3.25::x:7.36, or about 2.3 sacks. The number of parts of sand required equals the value of x in the equation 1:2.5::2.3:x, or 5.75 parts. There are 100 lb of sand in a "part," and 100 lb of gypsum in a sack. Therefore, for the base coat you will need 230 lb of gypsum and 575 lb of sand. See table 6-1 for physical properties of base coat plasters.

MIXING PLASTER BY HAND

Equipment for plaster mixing by hand consists of a flat, shallow-sided MIXING BOX and a hoe; the hoe usually has a perforated blade. Mixed plaster is transferred from the mixing box to a MORTAR BOARD, similar to the one used in bricklaying. Men applying plaster pick it up from the mortar board.

In hand mixing, the dry ingredients are first placed in the mixing box and thoroughly mixed until a uniform color is obtained. The pile is then coned up and troughed, and the water is mixed in much as it is in hand concrete mixing. Mixing is continued until the materials have been thoroughly blended and proper consistency has been attained. With experience a man acquires a "feel" for proper consistency. Mixing should not be continued for more than 10 or 15 minutes after the materials have been thoroughly blended, because excessive agitation may hasten the rate of solution of the cementitious material and thereby cause accelerated set.

Table 6-1.–Physical Properties of Basecoat Plasters

plaster	gypsolite regular	gypsum plaster to sand by weight			gypsum plaster and vermiculite		gypsum plaster and perlite		gypsum wood fiber		concrete bond plaster
Mix	Mill Mix	1:1	1:2	1:3	100 lbs. 2 cu. ft.	masonry 100 lbs. 3 cu. ft.	100 lbs. 2 cu. ft.	masonry 100 lbs. 3 cu. ft.	neat	1:1 sand by wt.	Mill Mix
Approximate Compressive Strength, lb. per sq. in.	900	1600	1150	750	500	300	900	650	2300	1800	2300
Approximate Tensile Strength, lb. per sq. in.	160	250	190	120	130	90	160	100	450	300	400

117.362

Finish-coat lime plaster is usually handmixed on a small 5 ft by 5 ft mortar board called a FINISHING BOARD. If the lime used is hydrated lime, it is first converted to lime putty by soaking in an equal amount of water for 16 hours. In mixing the plaster, the lime putty is first formed into a ring on the finishing board. Water is then poured into the ring, and the gypsum or Keene's cement is then sifted into the water to avoid lumping. The mix is allowed to stand for 1 minute, after which the materials are thoroughly blended. Sand, if it is to be used, is then added and mixed in.

MIXING PLASTER BY MACHINE

A mortar mixing machine (fig. 6-5) is used for mixing plaster. It consists primarily of a metal DRUM containing MIXING BLADES, mounted on a chassis equipped with wheels for road towing. Mixing is accomplished either by rotation of the drum or by rotation of the blades inside the drum. Discharge into a wheelbarrow or other receptable is usually accomplished by tilting the drum as shown in figure 6-2.

Steps in the machine mixing of gypsum plaster are as follows:

For job-mixed gypsum plaster:

1. Put in the approximate amount of water. Approximate water amounts for various gypsum-aggregate proportions and the common aggregates are as follows:

Aggregate	Gypsum-Aggregate Proportions		
	1:2	1:2.5	1:3
Sand	6.8 gals	7.4 gals	8.2 gals
Perlite	7.7 gals	8.5 gals	9.1 gals
Vermiculite	9.0 gals	10.0 gals	10.1 gals

2. If sand is used, add approximately one-half of the aggregate. If perlite or vermiculite is used, add all the aggregate.
3. Add all the cementitious material.
4. Add the remainder of the sand aggregate.
5. Mix to required consistency, adding more water IF NECESSARY.

For ready-mix gypsum plaster:

1. Put in the approximate amount of water, as prescribed by manufacturer's instructions printed on the sack.
2. Add the plaster.
3. Mix to the required consistency, adding water IF NECESSARY.

PLASTERING

To attain complete structural integrity, a plaster layer must be uniform in thickness; also, a plane plaster surface must be flat enough to appear flat to the eye and to receive surface-applied materials (such as casings and other trim) without the appearance of noticeable spaces. Specified flatness tolerance is usually 1/8 in. in 10 ft.

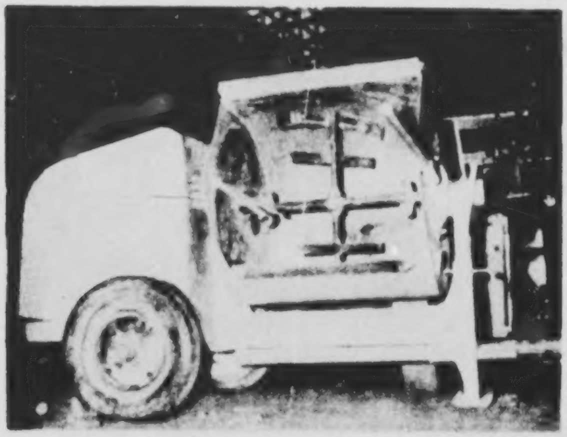


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Figure 6-5. – Mortar mixing machine.

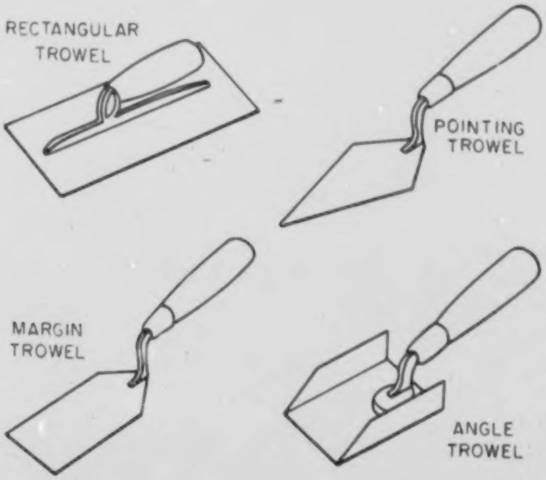

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Figure 6-6. –Plastering trowels.

PLASTERING TOOLS

Steel TROWELS are used to apply, spread, and smooth plaster. The shape and size of the blade of a trowel is determined by the purpose for which the tool is to be used and the manner of using it.

The four common types of plastering trowels are shown in figure 6-6. The RECTANGULAR TROWEL, with a blade approximately 4 1/2 in. wide by 11 in. long, serves as the principal conveyor and manipulator of plaster. The POINTING trowel, 2 in. wide by about 10 in. long, is designed for use in places where the rectangular trowel won't fit. The MARGIN trowel is another smaller trowel, similar to the pointing trowel, but with a square rather than a pointed end. The ANGLE trowel is used for finishing corner angles formed by adjoining right-angle plaster surfaces.

The HAWK (fig. 6-7) is a square, lightweight sheet metal platform with a vertical central handle, used for carrying mortar from mortar board to the place where it is to be applied. The plaster is then removed from the hawk with the trowel. The size of a hawk varies from 10 in. square to 14 in. square.

The FLOAT is glided over the surface of the plaster, to fill voids and hollows or to level bumps left by previous operations, and to impart a texture to the surface. Common types of floats are shown in figure 6-8. The WOOD

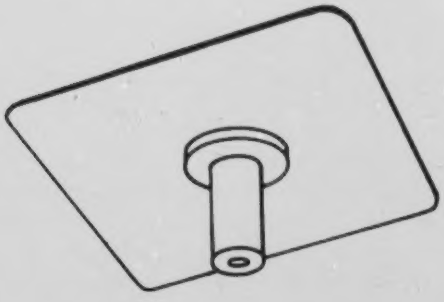

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Figure 6-7. – Hawk.

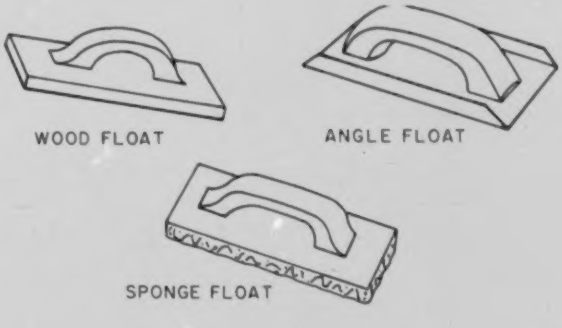

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Figure 6-8. –Plastering floats.

float has a wood blade, the ANGLE float a stainless steel or aluminum blade. The SPONGE float is faced with foam rubber or plastic, intended to attain a certain surface texture. A CARPET float is similar to a sponge float, but faced with a layer of carpet material. A CORK float is faced with cork.

A float blade is 4 or 5 in. wide and about 10 in. long.

The ROD and STRAIGHTEDGE consists of a wood or lightweight metal blade 6 in. wide and from 4 to 8 ft long. This is the first tool used in leveling and straightening applied plaster between the grounds. A wood rod has a slot for a handle cut near the center of the blade. A metal rod usually has a shaped handle running the length of the blade. A wood rod is shown in figure 6-9.

The FEATHEREDGE (fig. 6-9) is similar to the rod, except that the blade tapers to a sharp edge. It is used to cut in corners and to shape sharp, straight lines at corner lines of intersection.

The DARBY (fig. 6-10) is, in effect, a float with an extra-long (3 1/2 to 4 ft) blade, equipped with handles for two-handed manipulation. It is used for further straightening of the base coat after rodding is completed; also to level plaster screeds and to level finish coats. The blade of the darby is held nearly flat against the plaster surface, and in such a way that the line of the edge makes an angle of about 45° with the line of direction of the stroke.

When a plaster surface is being leveled, the leveling tool must move over the plaster smoothly. If the surface is too dry, lubrication must be provided by moistening. In base coat operations this is accomplished by dashing or brushing water on with a water-carrying brush called a BROWNING brush. This is a fine-bristled brush about 4 or 5 in. wide and 2 in. thick, with bristles about 6 in. long. For finish coat operations a FINISHING brush with softer, more pliable bristles is used.

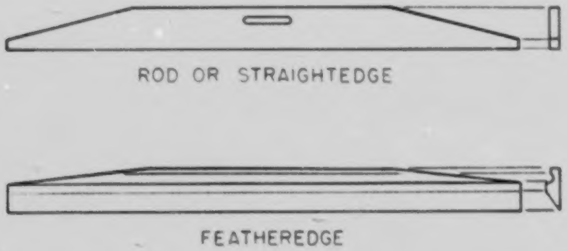

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Figure 6-9. –Rod or straightedge and featheredge.

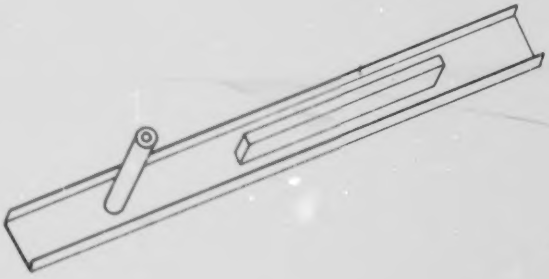

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Figure 6-10. –Darby.

A MECHANICAL TROWEL (often called a POWER TROWEL) is an electrically operated rotating trowel which weighs about 6 lbs and resembles a 6-bladed fan. There are usually two sets of blades, one more flexible than the other. The flexible set is used for preliminary troweling, the stiffer set for final troweling. Mechanical troweling can be done to within 1/2 in. of corner angles, leaving the angles to be finished by angle troweling.

There are two types of PLASTERING MACHINES. The WET MIX PUMP carries mixed plaster from the mixing machine to a hose nozzle. The DRY MIX machine carries dry ingredients to a mixing nozzle where water under pressure combines with the mix and provides spraying force. Most plastering machines are of the wet mix pump variety.

A wet mix pump may be of the WORM DRIVE, PISTON PUMP, or HAND HOPPER type. In a worm drive machine, mixed plaster is fed into a hopper and forced through the hose to the nozzle by the screw action of a rotor and stator assembly in the neck of the machine. A machine of this type has a hopper capacity of from 3 to 5 cu ft, and can deliver from 0.5 to 2 cu ft of plaster per minute.

On a piston pump machine a hydraulic, air-operated, or mechanically operated piston supplies the force for moving the wet plaster. On a hand hopper machine the dry ingredients are placed in a hand-held hopper just above the nozzle. Hopper capacity is usually around 1/10 cu ft. These machines are used principally for applying finish plaster.

Machine application cuts down on the requirements for the use of the hawk and trowel in initial plaster application; however, the use of straightening and finishing handtools remains about the same for machine-applied plaster.

PLASTERING CREWS

A typical plastering crew for hand application consists of a crew chief, 2 to 4 plasterers, and 2 to 4 TENDERS. The plasterers, under the crew chief's supervision, set all levels and lines and apply and finish the plaster. The tenders mix the plaster, deliver it to the plasterers, construct scaffolds, handle materials, and do cleanup tasks.

For machine application a typical crew consists of a NOZZLEMAN who applies the material, 2 or 3 plasterers leveling and finishing, and 2 or 3 tenders.

APPLICATION OF PLASTER

Lack of uniformity in the thickness of a plaster coat detracts from the structural performance of the plaster, and the thinner the coat, the smaller the permissible variation from uniformity. Specifications usually require that plaster be finished "true and even, within 1/8 in. tolerance in 10 ft, without waves, cracks, or imperfections." The standard of 1/8 in. appears to be the closest practical tolerance to which a plasterer can work by the methods commonly in use.

The importance of adhering to the recommended minimum thickness for the plaster cannot be overstressed. A plaster wall becomes more rigid as thickness over the minimum recommended increases—which means in effect that the tendency to cracking increases as thickness increases. However, tests have shown that a reduction of thickness from a recommended minimum of 1/2 in. to 3/8 in., with certain plasters, decreases cracking resistance by as much as 60 percent, while reduction to 1/4 in. decreases it by as much as 82 percent.

Base Coat Application

GYPSUM BASE COATS.—The sequence of operations in three-coat gypsum plastering is as follows:

1. Install the plaster base.
2. Attach the grounds.
3. Apply the scratch coat approximately 3/16 in. thick.
4. Before the scratch coat sets, RAKE and CROSS-RAKE. This procedure consists of scratching with a tool that leaves furrows approximately 1/8 in. deep, 1/8 in. wide, and 1/2 to 3/4 in. apart. The furrows are intended to improve the bond between the scratch coat and the brown coat.
5. Allow the scratch coat to set firm and hard.
6. Apply plaster screeds if required.
7. Apply the brown coat to the depth of the screeds.
8. Using the screeds as guides, straighten the surface with a rod.
9. Fill in any hollows and rod again.
10. Level and compact the surface with a darby; then rake and cross-rake to receive the finish coat.
11. Define angles sharply with angle float and featheredge, and trim back plaster around grounds so that finish coat can be applied flush with grounds.

The two-coat method is used with gypsum plaster over a gypsum lath or a masonry base. Steps are as follows:

1. Install the base if necessary.
2. Attach the grounds and apply plaster screeds if necessary.
3. Apply the first thickness, and double back immediately with a second thickness to the depth of the screeds; because of this procedure, two-coat work is frequently called DOUBLE-BACK.

The remaining steps are similar to the last four steps discussed in three-coat work.

Finish Coat Application

Interior plaster may be finished by troweling, floating, or spraying. Troweling gets a smooth finish, floating or spraying a finish of a desired surface texture.

LIME PUTTY-GYPSUM TROWEL FINISH.–Finish plaster made of gypsum gauging plaster and lime putty (familiarly called WHITE COAT or PUTTY COAT) is the most widely used material for smooth finish coats. A putty coat is usually applied by a team of two or more men. Steps are as follows:

1. One man applies plaster at the angles.
2. Another man follows immediately, straightening the angles with a rod or featheredge.
3. The remaining surface is covered with a SKIM coat of plaster. Pressure on the trowel must be sufficient to force the material into the rough surface of the base coat, to ensure good bond.
4. The surface is immediately doubled back to bring the finish coat to final thickness.
5. All angles are floated, with additional plaster being added if required to fill hollows.
6. The remaining surface is floated, and all hollows filled. This operation is called DRAWING UP; the hollows being filled are called CAT FACES.
7. The surface is allowed to DRAW for a few minutes. As the plaster begins to set, the surface water glaze disappears, and the surface becomes dull. At this point, troweling should begin. The plasterer holds the water brush in one hand and the trowel in the other, so troweling can be done immediately after water is brushed on.
8. Water is brushed on lightly and the entire surface is rapidly troweled, with enough pressure fully to compact the finish coat. The troweling operation is repeated until the plaster has set.

The sequence of steps for trowel finishes for other types of finish plaster are about the same. Gypsum finish plaster requires less troweling than white coat plaster. Regular Keene's cement requires longer troweling, but quicksetting Keene's cement requires less.

Steps in float finishing are about the same as those described for trowel finishing, except, of course, that the final finish is obtained with the float. A surface is usually floated twice; a rough floating with a wooden float first, then final floating with rubber or carpet float. The plasterer applies brush water with one hand while the float in his other hand moves in a circular motion immediately behind the brush.

A spray finish is machine-applied. The degree of coarseness of the surface texture is controlled by the air pressure at the nozzle, the distance the nozzle is held from the surface, and the composition of the plaster mix, particularly the aggregate. A spray finish is usually applied in two thin applications. After the first coat has been applied, all depressions, holes, or irregularities are touched up by hand to prevent their showing in the final coat.

Some special interior finish textures are obtained otherwise than by floating, or by procedures used in addition to floating. A few of these are as follows:

STIPPLED FINISH.–After the finish coat has been applied, additional plaster is daubed over the surface with a stippling brush.

SPONGE FINISH.–By pressing a sponge against the surface of the finish coat, a very soft, irregular texture can be obtained.

DASH COAT FINISH.–This texture is obtained by throwing plaster onto the surface from a brush. It produces a fairly coarse finish, which can be modified by brushing the plaster with water before it sets.

TRAVERTINE FINISH.–The plaster is jabbed at random with a whisk broom, wire brush, or other tool that will form a dimpled surface. As the plaster begins to set, it is troweled intermittently to form a pattern of rough and smooth areas.

PEBBLE DASH.–This is a rough finish obtained by throwing small pebbles or crushed stone against a newly plastered surface. If necessary, a trowel is used to press the stones lightly into the plaster.

WALL TILES

Ceramic and plastic tiles are used for wall finishes in bathrooms, shower rooms, galleys, and other locations where a highly sanitary, easily cleaned, impervious wall finish is required. Ceramic tile, being more durable than plastic tile, is the most commonly used tile for wall finishes. Plastic tile is generally used in situations where permanency is secondary to expediency. Such would be the case in the construction of advanced base and temporary structures.

Wall tiles are available in 4 1/4 x 4 1/4, 6 x 4 1/4, and 6 x 6 inch sizes; however, the standard 4 1/4-inch square tile is the size most often used. Margins, corners, and baselines are finished with TRIM UNITS of various shapes and sizes. Available shapes and sizes of trim units are shown on a TRIM UNIT CHART provided by the manufacturer.

The following discussion is not intended to acquaint you with each of the surfaces to which tile may be applied or to describe in detail the materials and procedures used in their preparation. The intent is to acquaint you with the principles involved in the preparation of tile bases and tile installation.

BASE PREPARATION

Before tile installation begins, the surfaces to receive the tile should be checked to ensure that the following criteria is met. All surfaces should be dry, clean, free of waxy or oily films, and structurally firm. The plane of the surface to be tiled should be plumb, level and true with square corners. Variations of more than 1/8 inch in 8 feet from the required plane are not acceptable.

Mortar Bed Preparation

If the surface is to be prepared, the same criteria holds true. For instance, for mortar bed setting of ceramic tile on a wall with wooden studs, a layer of waterproof paper (such as 15-lb asphalt saturated felt) is first tacked to the studs in shingle fashion and lapped 3 inches. Metal lath is then nailed over the lapped paper to provide the base for the mortar bed. A scratch coat for application as a foundation coat must be not less than 1/4 inch thick. For walls, the mix should consist of 1-part portland cement, 4-parts dry sand or 5-parts damp sand, and 1/5-part hydrated lime by volume. For ceilings, the mix should consist of 1-part portland cement, 2 1/2-parts dry sand or 3-parts damp sand, and 1/2-part hydrated lime by volume. If the scratch coat surface varies more than 1/4 inch in 8 feet from the required plane, or if a mortar thickness of more than 3/4 inch is required to build out to the finished tile surface, a leveling coat containing the same ingredient proportions as the scratch coat should be applied. While still plastic, the scratch coat (and leveling coat if required) should be deeply scored or scratched and cross-scratched in preparation for the setting bed mix (commonly called float coat). The scratch coat should be protected, kept reasonably moist during the seasoning period, and allowed to cure 24 hours before applying the float coat. The same holds true for the leveling coat if required.

Like the scratch coat, the ingredient proportions for the float coat vary for wall and ceiling installations. For walls, the mix should range from 1-part portland cement, 1/2-part hydrated lime, and 5-parts damp sand to 1-part portland cement, 1-part hydrated lime, and 7-parts damp sand, by volume. For ceilings, the mix should consist of 1-part portland cement, 2 1/2-parts dry sand or 3-parts damp sand, and 1/2-part hydrated lime, by volume. Mortar ingredients should be mixed thoroughly before adding just enough water to obtain the desired consistency. Prior to application of the float coat, saturate the preceding surface coat evenly and allow the excess surface water to run off. The float coat (mortar setting bed), which should not exceed 3/4 inch, is brought flush with screeds or other guides, so placed as to give a true and even surface at the proper distance from the finished face of the tile.

MORTAR BED SETTING.—Wall tile should be thoroughly soaked in clean water before it is set. It is set by troweling a skim coat of neat portland cement mortar on the float coat, or applying a skim coat to the back of each tile unit, and immediately floating the tile into place. Joints must be straight, level, perpendicular, and of even width not exceeding 1/16 inch. Wainscots are built of full courses, which may extend to a greater or lesser height, but in no case more than 1 1/2 inches difference than the specified or figured height. Vertical joints must be maintained plumb for the entire height of the tile work.

All joints in wall tile should be grouted full with a plastic mix of neat white cement or commercial tile grout immediately after a suitable area of the tile has been set. The joints should be tooled slightly concave and the excess mortar cut off and wiped from the face of tile. Any interstices or depressions in the mortar joints after the grout has been cleaned from the surface should be roughened at once and filled to the line of the cushion edge (if applicable) before the mortar begins to harden. Tile bases or coves should be solidly backed with mortar. All joints between wall tile and plumbing or other built-in fixtures should be made with a light-colored calking compound. Immediately after the grout has had its initial set, tile wall surfaces should be given a protective coat of noncorrosive soap or other approved coating material. Wall tile installed over existing and patched or new plaster surfaces in an existing building are completed as described, except that such wall tile is applied by the adhesive method (discussed in the following section).

Where wall tile is to be installed in areas subject to intermittent or continual wetting, the wall areas should be primed as recommended by the manufacturer of the adhesive used.

Adhesive Bed Preparation

Preparation for adhesive bed setting of ceramic or plastic tile on a wall with wooden studs can be accomplished using 3/8 inch (or larger) Type C exterior plywood for dry areas, or 1/2 inch water-resistant gypsum wallboard for wet areas, such as tub recesses or other locations subject to similar wetting conditions. Whichever material is used, variations in the plane of the wall surface must not exceed 1/8 inch in 8 ft. If plywood is used as the base material, prior to installation all panel edges should be sealed with a quality exterior primer or aluminum paint. Plywood panels should be applied with the direction of the face grain perpendicular to the studs and spaced 1/8 inch apart to allow for expansion. In situations where it is desired to install the plywood with the face grain parallel to the studs, 1/2 inch thick (or greater) plywood should be used. Nails should be spaced 6 inches on center at panel edges and 12 inches on center at intermediate supports. Solid 2 x 4 blocking should be provided between framing members at horizontal panel edges. After panel installation, seal around all pipes and conduits which go through the backing with a sealant recommended by the tile manufacturer. Porous surfaces such as gypsum plaster, asbestos-cement board, and plywood should be primed with a primer recommended by the adhesive manufacturer as proper for the particular backing and compatible with the adhesive.

ADHESIVE BED SETTING.–Wall tile may be installed using adhesives either by the floating method or by the buttering method. In the floating method, apply the adhesive uniformly over the prepared wall surface, using quantities recommended by the adhesive manufacturer. Use a notched trowel held at the proper angle to ensure a uniformly spread coating of the proper thickness. Touch up thin or bare spots by an additional coating of adhesive. The area coated at one time should not be any larger than that recommended by the manufacturer of the adhesive. In the buttering method, daub the adhesive on the back of each tile in such amount that the adhesive, when compressed, will form a coating not less than 1/16 inch thick over 60 percent of the back of each tile.

Joints must be straight, level, plumb, and of even width not exceeding 1/16 inch. When the floating method is used, one edge of the tile is pressed firmly into the wet adhesive, the tile snapped into place in a manner to force out all air, then aligned by using a slight twisting movement. Tile should not be shoved into place. Joints must be cleaned of any excess adhesive to provide for a satisfactory grouting job.

When the buttering method is used, tile is pressed firmly into place, using a "squeegee" motion to spread the daubs of adhesive. After the adhesive partially sets, but before it is completely dry, all tiles must be realigned so that faces are in the same plane and joints are of proper width, with vertical joints plumb and horizontal joints level.

Wainscots are built of full courses to a uniform height. The wainscots height may be adjusted somewhat to accommodate full courses, but the adjustment should not exceed or be less than 1 1/2 inches from the specified height.

The adhesive should be allowed to set for 24 hours before grouting is done. Joints must be cleaned of dust, dirt, and excessive adhesive, and should be thoroughly soaked with clean water before grouting. A grout consisting of portland cement, lime, and sand may be used. With the advent of thin-set mortars and frequent use of adhesives, more care must be exercised in the selection and use of tile grout. For this reason a ready-mix grout recommended by the ceramic or plastic tile manufacturer should be used. In any case, the grout should be water resistant and nonstaining.

Nonstaining calking compound should be used at all joints between built-in fixtures and tilework, and at the top of ceramic tile bases, to ensure complete waterproofing. Internal corners should be calked before corner bead is applied.

Cracked and broken tile should be replaced promptly to protect the edges of adjacent tile and to maintain waterproofing and appearance. Timely pointing of displaced joint material and spalled areas in joints is necessary to keep tiles in place.

Newly tiled surfaces should be cleaned to remove job marks and dirt. Cleaning should be done according to the tile manufacturer's recommendations to avoid damage to the ceramic or plastic surfaces.

SUSPENDED ACOUSTIC CEILING SYSTEMS

Suspended acoustical ceiling systems can be installed to lower a ceiling, finish off exposed joints, cover damaged plaster or make any room quieter and brighter. The majority of the systems available are primarily designed for acoustical control; however, many manufacturers offer systems which integrate the functions of lighting, air distribution, fire protection and acoustical control. Individual characteristics of acoustical tiles, including sound absorption coefficients, noise reduction coefficients, light reflection values, flame resistance, and architectural applications, are available from the manufacturer. Tiles are available in 12 to 30 inch widths, 12 to 60 inch lengths, and 3/16 to 3/4 inch thickness. The larger sizes are referred to as panels. The most commonly used panels in suspended ceiling systems are the standard 2 x 2 and 2 x 4 ft acoustic panels composed of mineral or cellulose fibers.

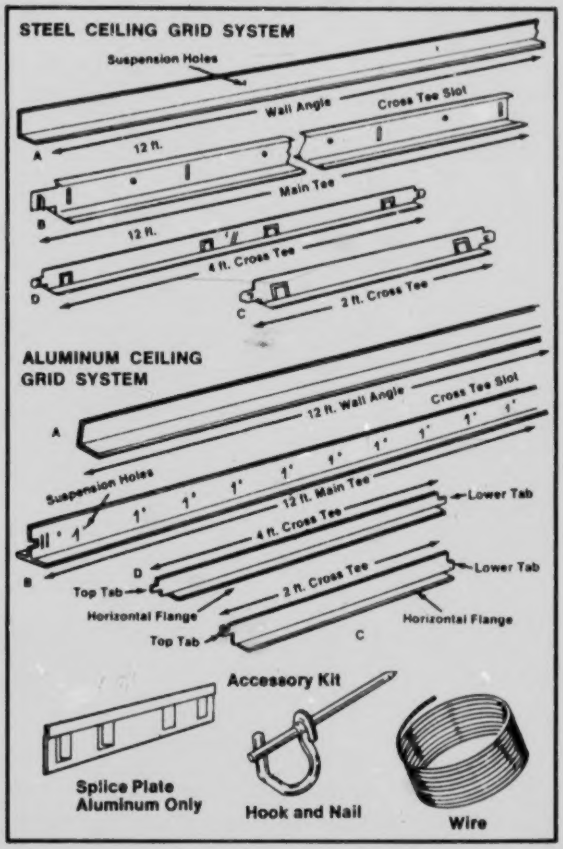
It is beyond the scope of this training manual to acquaint you with each of the suspended acoustical ceiling systems in use today. Just as the components of these systems vary according to manufacturers, so do the procedures involved in their installation. With this in mind, the following discussion is designed to acquaint you with the principles involved in the installation of a typical suspended acoustical ceiling system that is adaptable to both standard sizes of acoustical panels.

PREPARATION FOR INSTALLATION

The success of a suspended ceiling project, as with any construction project, is just as dependent on planning as it is with construction methods and procedures. Planning in this case involves the selection of a grid system (either steel or aluminum), the selection and layout of a grid pattern (either 2 x 2 or 2 x 4 ft), and the determination of material requirements. Figure 6-11 shows the major components of a steel and aluminum ceiling grid system which are used for the 2 x 2 or 2 x 4 ft grid patterns shown in figure 6-12.

Grid Pattern Layout

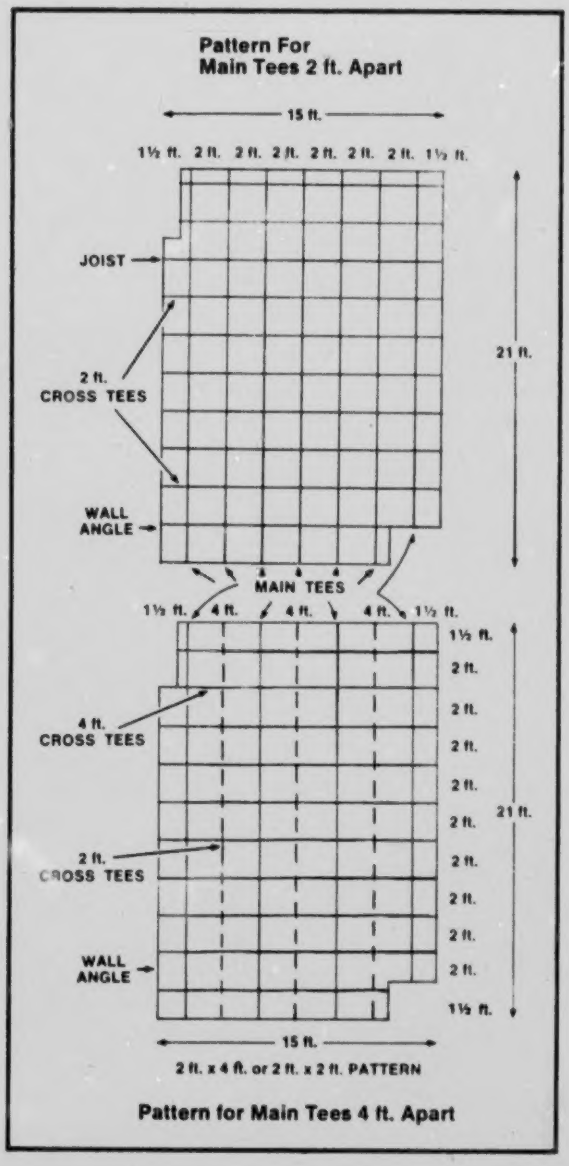
The layout of a grid pattern and the material requirements are based on the ceiling measurements. Ceiling measurements are determined by measuring the perimeter of the room at the new ceiling height. If ceiling length and/or width is not divisible by 2 ft, increase that dimension to the next higher foot divisible by 2 ft. For example, if a ceiling measures 13 ft, 7 in. x 10


STEEL CEILING GRID SYSTEM
Suspension Holes
Wall Angle
Cross Tee Slot
A
12 ft.
Main Tee
B
12 ft.
4 ft. Cross Tee
D
2 ft. Cross Tee
C
ALUMINUM CEILING GRID SYSTEM
A
12 ft. Wall Angle
Cross Tee Slot
1'
Suspension Holes
12 ft. Main Tee
Lower Tab
4 ft. Cross Tee
B
D
Top Tab
2 ft. Cross Tee
Lower Tab
Horizontal Flange
Horizontal Flange
Top Tab
C
Accessory Kit
Splice Plate
Aluminum Only
Hook and Nail
Wire

117.363

Figure 6-11. —Grid system components.

ft, 4 in., it should be considered as being a 14 x 12 ft ceiling for material and layout purposes. The next step is to draw a layout on graph paper, making sure that the main tees run perpendicular to the joints. Position the main tees on your drawing so that the border panels at room edges are equal and as large as possible. Try several layouts to see which looks best with the main tees. Draw-in cross tees so border panels at room ends are equal and as large as possible. Try several combinations to determine the best one. For 2 x 4 ft patterns, space cross tees 4 feet apart. For 2 x 2 ft patterns, space cross tees 2 feet apart. For smaller areas, the 2 x 2 ft pattern is recommended.


Pattern For Main Tees 2 ft. Apart

15 ft.
1½ ft. 2 ft. 2 ft. 2 ft. 2 ft. 2 ft. 2 ft. 1½ ft.
JOIST
2 ft.
CROSS TEES
21 ft.
WALL
ANGLE
MAIN TEES
1½ ft. 4 ft. 4 ft. 4 ft. 1½ ft.
1½ ft.
2 ft.
2 ft.
2 ft.
2 ft.
2 ft.
2 ft.
2 ft.
2 ft.
2 ft.
1½ ft.
4 ft.
CROSS TEES
21 ft.
2 ft.
CROSS TEES
WALL
ANGLE
15 ft.
2 ft. x 4 ft. or 2 ft. x 2 ft. PATTERN

Pattern for Main Tees 4 ft. Apart

117.364

Figure 6-12. —Grid patterns.

Material Requirements

As indicated in figure 6-12, wall angles and main tees come in 12 ft pieces. Using the actual ceiling measurements (perimeter of room at suspended ceiling height), the number of pieces of wall angle can be determined by dividing the total perimeter by 12 and adding 1 additional piece for any fraction.

The number of 12 ft main tees, 2 ft and/or 4 ft cross tees can be determined by counting the number on the grid pattern layout. In determining the number of 2 ft or 4 ft cross tees for border panels, you must remember that no more than 2 border tees can be cut from one cross tee.

INSTALLATION

The tools normally required for the installation of a grid system of the type under discussion include a hammer, chalk or pencil, pliers, tape measure, screwdriver, hacksaw, knife, and tinsnips. With these tools on hand you can begin installation by installing the wall angles, then the suspension wires followed by the main tees, cross tees, and acoustical panels.

Wall Angles

The first step is to install the wall angles at the new ceiling height which in the case of the grid system under discussion can be as close as 2 inches below the existing ceiling. Begin by marking a line around the entire room to indicate wall angle height and to serve as a level reference. Make sure to mark continuously to ensure that the lines at intersecting walls meet. (See fig. 6-13). The next step is to install the wall angle. On gypsum board, plaster or paneled walls, install wall angles with nails or screws. On masonry walls, use concrete nails spaced 24 inches apart taking care to ensure that the wall angle is level. (See figure 6-14 for treatment at corners.) After the wall angles are installed, the next step is to attach the suspension wires.

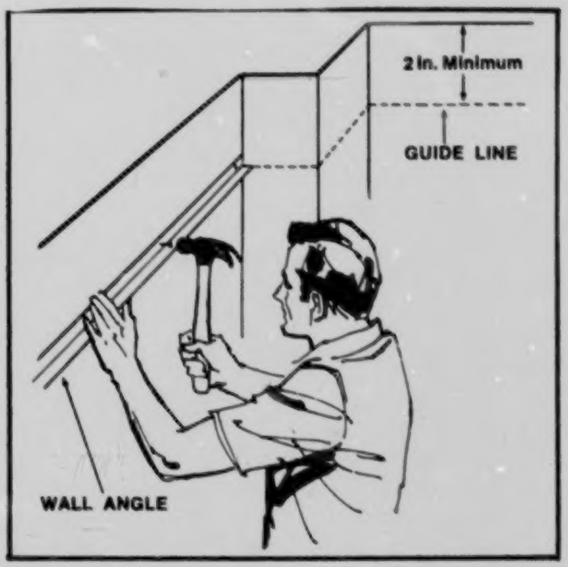


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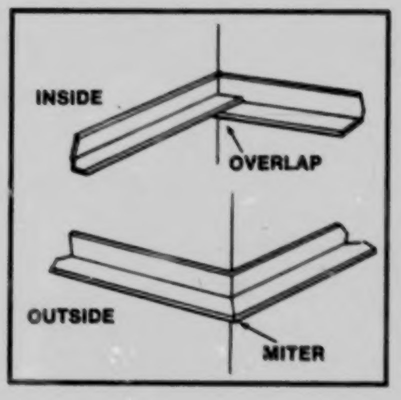
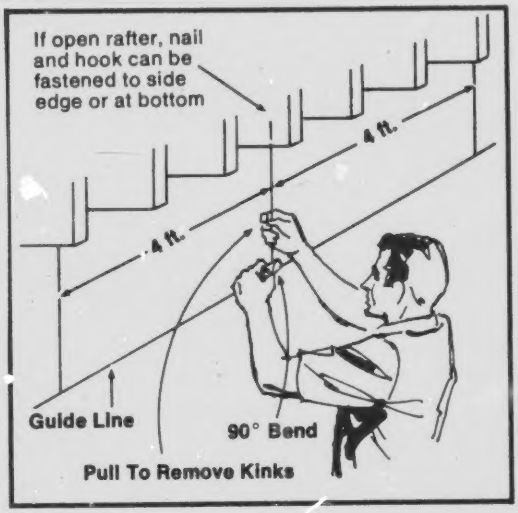
Figure 6-13. —Wall angle installation.



117.366
Figure 6-14. —Corner treatment.

Suspension Wires

Suspension wires are required every 4 feet along main tees and on each side of all splices. Attach wires to the existing ceiling with nails or screw eyelets. Before attaching the first wire, measure the distance from the wall to the first main tee. Then stretch a guideline from opposite wall angles to show the correct position of the first main tee. Position suspension wires for the first tee along the guide. Wires should be cut to proper length, which is at least 2 inches longer than the distance between the old and new ceiling. Attach additional wires at 4 ft intervals. Pull wires to remove kinks and make 90° bends in the wires where they intersect the guideline. Move the guideline as required for each row. (See fig. 6-15). After the suspension wires are attached, the next step is to install the main tees.

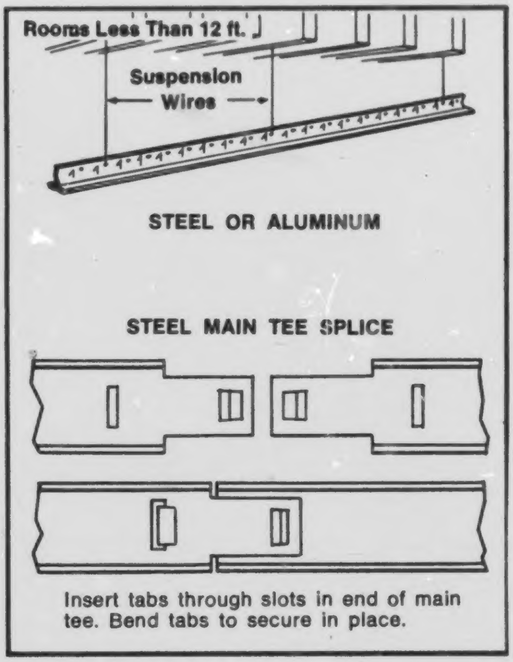

If open rafter, nail and hook can be fastened to side edge or at bottom
4 ft.
4 ft.
Guide Line
90° Bend
Pull To Remove Kinks

117.367
Figure 6-15. –Suspension wire installation.

Main Tees

Main tees, 12 ft or less in length, are installed by resting the ends on opposite wall angles and inserting the necessary suspension wires. (See fig. 6-16.) Hang one wire near the middle of the main tee, level and adjust wire length, then secure all wires by making the necessary turns in the wire.

If the main tees required are over 12 ft in length they must be cut to ensure that the cross tees will not intersect the main tee at a splice joint. (See fig. 6-17.) Starting at the same wall end, the first steel tee in each row should be shortened 6 inches and the first aluminum tee shortened 12 inches. Begin installing by resting the cut end on the wall angle and attach the suspension wire closest to the opposite end. Attach the remaining suspension wires making sure the main tee is level before securing. The remaining tee or tees are installed by making the necessary splices as shown in figures 6-16 and 6-18 and resting the end on the opposite wall angle. After the main tees are installed, leveled and secured the next step is to install the cross tees.



Insert tabs through slots in end of main tee. Bend tabs to secure in place.

117.368
Figure 6-16. –Main tee suspension and steel tee splice.

Cross Tees

Aluminum cross tees have "high" and "low" tab ends which provide easy positive installation without tools. Installation begins by cutting border tees (when necessary) to fit between the first main tee and wall angle. Cut off the high tab end and rest this end in the main tee slot. Repeat this procedure until all border tees are installed on one side of the room. Continue across the room, installing the remaining cross tees in accordance with your grid pattern layout. An aluminum cross tee assembly is shown in figure 6-19. At the opposite wall angle, cut off the low tab of the border tee and rest the cut end on the wall angle. If the border edge is less than half the length of the cross tee, you can use the remaining portion of the border tee that was previously cut.

Steel cross tees have the same tab on both ends and, like the aluminum tees, they do not require tools for installation. The procedures used in their installation are the same as those

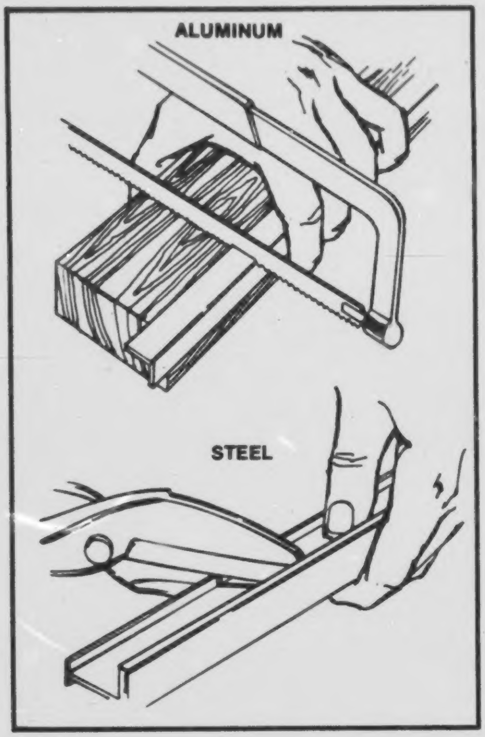

ALUMINUM
STEEL

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Figure 6-17. —Cutting methods.

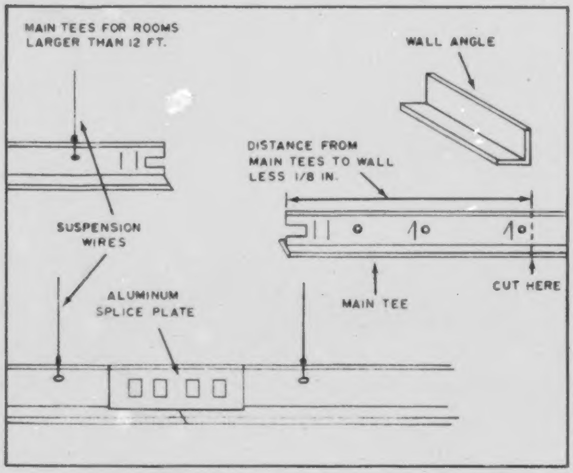
MAIN TEES FOR ROOMS LARGER THAN 12 FT.
WALL ANGLE
DISTANCE FROM MAIN TEES TO WALL LESS 1/8 IN.
SUSPENSION WIRES
ALUMINUM SPLICE PLATE
MAIN TEE
CUT HERE

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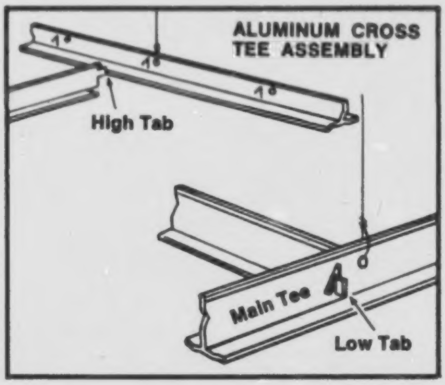
Figure 6-18. —Main tee suspension and aluminum tee splice.


ALUMINUM CROSS TEE ASSEMBLY
High Tab
Main Tee
Low Tab

117.371

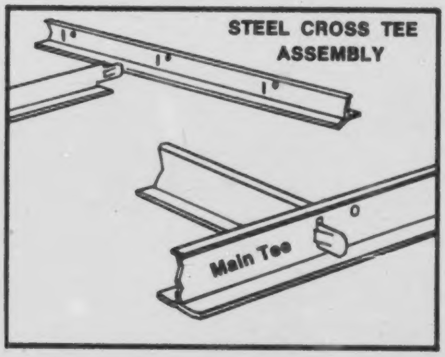
Figure 6-19. —Aluminum cross tee assembly.

just mentioned for aluminum. A steel cross tee assembly is shown in figure 6-20. The final step after completion of the grid system is the installation of the acoustical panels.

Acoustical Panels

Panel installation is started by laying in all full ceiling panels. Border panels should be installed last after they have been cut to proper size. To cut the panel, turn the finish side up, scribe with a sharp utility knife, and saw with a sharp handsaw having 12 or 14 teeth per inch.

The majority of the ceiling panel patterns are random and do not require orientation. However, some fissured panels are designed to be installed in a specific direction and are so marked on the back with directional arrows.


STEEL CROSS TEE ASSEMBLY
Main Tee

117.372

Figure 6-20. —Steel cross tee assembly.

When installing panels on a large project, you should work from several cartons. The reason for this is that color, pattern or texture might vary slightly, and by working from several cartons you will avoid a noticeable change in uniformity.

Since ceiling panels are pre-finished, handle with care. Keep surfaces clean by using talcum powder or corn meal on your hands or wearing clean canvas gloves. If panels do become soiled, art gum or a plastic type wallpaper can be used to remove spots, smudges, and fingerprints. Some panels can be washed with a light application of a sponge dampened with a mild detergent solution. However, before washing or performing other maintenance services such as painting, always refer to the manufacturer's instructions.

Integrated Systems

As previously indicated, some ceiling systems integrate the functions of lighting, air distribution and fire protection with acoustical control. When working with such a system it is up to you to coordinate the activities of the other rates involved. This means working with the CEs and UTs when planning and scheduling the work so that the installation of the electrical, air distribution, sprinkler, and acoustical systems is in conformance with the manufacturer's recommendations.

CHAPTER 7

LIGHT FRAME CONSTRUCTION

When a complete set of drawings is made for a wood frame building, large scale details are usually shown for typical sections, joints, and other unusual construction features. Your knowledge of the theory of structures, the design principles of wood frame buildings, and of the different functions of structural members will aid you in the supervision of light frame construction operations using such drawings. This knowledge will also enable you to make structural modifications which are consistent with design and engineering principles.

In this chapter we will discuss the design principles of wood frame buildings. A wood frame building is one in which the frame consists principally of load-bearing members made of structural lumber such as those used in barracks, SEA huts, and the like. Information is also provided on the principles of constructing wood trusses and the layout of foundation and floor slabs for steel rigid frame buildings.

THEORY OF STRUCTURES

A structure is built of parts, called MEMBERS, intended to support and to transmit loads while remaining in equilibrium relative to each other. The points at which members are connected are called JOINTS, and the methods of connection are determined principally by the kinds of material being connected. All structures, whether bridges, buildings or towers, have certain factors in common which are considered in the design. As a Builder whose tasks include the construction of various types of structures, an understanding of these basic factors is essential.

1. Loads. The principal loads present in every structure are classified as DEAD LOADS and LIVE LOADS.

Dead Load means the weight of the structure itself, which increases gradually as the structure is being built and remains constant, in most cases, once it has been completed. It must be remembered, however, that any modifications made to the structure must be considered as to their effect on the existing load-bearing members. In some cases, the addition of partitions or heating and air-conditioning equipment, not compensated for in the original design, might require the relocation or addition of load-bearing members so as to safely handle the increased dead load. The weight of all structural members plus floors, walls, heating equipment, and all other nonmovable items in a building are also considered as dead load.

Live Load means the weight of movable objects on the floor of the building or deck of a bridge or forces acting on their exteriors. This would mean people and furniture on the floor of a building, the traffic across a bridge, and other external forces such as wind, snow, ice, wave action, etc.

2. Load Distribution. All structures are designed with the same basic theory of load distribution, which states that all live loads are supported by horizontal structural members. The loads are transmitted from the horizontal members to the supporting vertical members. Obviously, outside forces acting on the structure must be counteracted by members whose longitudinal axes or whose components are parallel to the external forces. Vertical members are supported by footings or foundation walls that rest on the ground. All structural loads are therefore

dispersed into the ground supporting the structure. The ability of the ground to support loads is called soil bearing capacity.

3. Soil bearing capacity. The bearing capacity of the ground is measured in pounds per square foot (psf), and is determined by test; it varies for different soils. The area over which a footing extends is a factor in distributing the load received from a column in accordance with the bearing capacity of the soil. The size of the footing, therefore, is determined by the bearing capacity of the soil on which the structure is built.

4. Uniformly distributed and Concentrated Loads. The load of a structural member is classified as UNIFORMLY DISTRIBUTED or CONCENTRATED. A concentrated load is exerted at a particular point on the member as. for example, the load of a beam on a girder. A uniformly distributed load is one which is spread throughout a member, such as a slab on a beam.

5. Eccentric Loading. Eccentric loading occurs when force on the member such as a column is not applied at the center of the column, but rather off center.

6. Stress. The loading of structural members has a tendency to deform them. The ability of a member to withstand certain kinds of deformation is called STRESS.

a. Tension. Tension is the longitudinal stress or pull that tends to lengthen a member. The ability of the member to resist this pull is the TENSILE STRENGTH of the member.

b. Compression. Compression is the force that tends to shorten or compress a member into a smaller area. Actually, compression is the opposite of tension. The stresses set up in the member are called COMPRESSIVE STRESSES.

c. Flexural or Bending. The combinations of compressive and tensile stresses are called FLEXURAL or BENDING STRESSES. These stresses are greatest at the top and bottom of the member and zero at the neutral axis which is usually near the center of the depth, depending on the shape and composition of the member. This generally happens on a horizontal member, such as a beam. The material on the upper side of the beam is compressed or shortened, and that on the lower side is elongated. The STIFFNESS of a member is its ability to resist bending.

d. Shear. Shear is the force that is applied to a horizontal surface tending to cut it in the vertical plane. The stresses set up in the member are called SHEARING STRESSES.

e. Torsion. Torsion is expressed as the ability of a member to withstand the stresses set up when the member remains stationary at one end while the other end is revolved or twisted.

f. Deflection. Deflection is caused by bending, by the shortening and lengthening of opposite sides of a member. This is a very important factor in the design of long beams and columns.

g. Strength. The strength of a structural member refers to that member's ability to withstand loads without failure. The design and use of a member determines strength in a particular instance. A structural member is never used in a case where its ultimate strength is needed to support design conditions. A SAFETY FACTOR must always be allowed for.

The above factors may all be considered in the design of a wood frame building, depending upon its type, purpose and cost. The type and use of a building play an important role in its design. It not only affects the building's architectural design but also affects its structural design. Based on a building's intended use, its physical and geographical location, the materials available, and the construction methods used, loads are calculated by which its structural members are designed.

From a design standpoint, it is impractical to consider the design factors under discussion individually. They must be considered collectively as each affects one or more of the others depending on the circumstances. The following sections are devoted to the design of the primary structural members in a wood frame building to include, Girders, Posts, Joists, Rafters, and Headers. In the discussion of these members you will discover how the design factors previously mentioned affect the design of the various members, individually and/or collectively as the case may be.

GIRDERS

A girder in small-house construction is a large beam, at the first-story line, which takes the place of an interior foundation wall and supports the inner ends of floor joists.

SELECTING AND INSTALLING GIRDERS

If a building is wider than 14 or 15 feet, it is generally desirable, and often necessary, to introduce additional support near the center to avoid the necessity of excessively heavy floor joists. To save expense and to eliminate partitions in the basement, it has become common practice to introduce girders resting on posts or columns. These girders and their supporting posts carry a relatively large part of the weight of the building. As it is often necessary for the Builder to decide upon their size and type, he should be well informed on their design.

Number and Location of Girders

In determining the number and location of girders, consideration must be given to the permissible length of joists, to the room arrangement, and to the location of bearing partitions.

LENGTH OF JOISTS.–In most houses one girder will suffice; but if the joist span exceeds 14 or 15 feet, for which a 2 by 10 inch member is usually required, considerable increase in joist sizes becomes necessary in most species, thus making another girder advisable.

To illustrate this point, suppose a building to be 17 feet 4 inches between inner faces of bearing walls. If no girders were used, with some species and grades of lumber, 2- by 14-inch or 3- by 10-inch joists would be required.

On the other hand, if a girder were used at the center of the building, the joist span would be only half of 17 feet 4 inches, or 8 feet 8 inches, for which, in most species of lumber, a 2 by 6 could be used. Furthermore, as joists over 14 or 16 feet long require two rows of bridging, it is well, as a means of economy, to keep joist lengths within 14 feet. If a building is more than 14 feet wide, it is usually better to introduce a girder.

ROOM ARRANGEMENT.–As it is desirable to locate the girder directly under, or very close to, bearing partitions to avoid the necessity of additional or larger joists, the room arrangement will usually determine the location of girders.

If girders are far apart, joists must be larger and girders stronger, which will tend to increase the cost. For this and other reasons it is desirable to place the girders as close together as will not unduly increase the cost of foundation work. From 8 to 14 feet is usually an economical spacing for girders.

Effects of Dimensions on Strength

The girder should be strong enough for its load, but any size larger than needed is waste. There are three principal factors that must be understood before attempting to determine the size of a wood girder: (1) The effect of length on strength; (2) the effect of width on strength; and (3) the effect of depth on strength.

LENGTH.–If an 8-foot plank is supported at the ends on sawhorses, and loads are evenly distributed throughout its length, it will tend to bend. If the plank is 16 feet long, with the same load per foot of length, it will bend more and will be likely to break. It is natural to think that if the length is doubled, the safe load will be reduced one-half; but experience has shown, and the theory of mechanics bears it out, that instead of carrying safely half the load the 16-foot plank is good for only one-quarter.

This applies to planks or beams carrying a load distributed uniformly along their entire lengths and to all joists and girders. The reason is that for each foot of length added to the beam, another foot of load is also added. For a single concertrated load at the center, however, increasing the span does not increase the load; and hence doubling the length decreases the safe load by only one-half.

Consequently the greater the unsupported length or span the stronger the girder must be. The strength can be increased in two ways–by using a stronger material or by using a larger beam. The beam may be enlarged by increasing the width or depth, or both.

WIDTH.–If the width is doubled, the strength is doubled, as is shown by many tests. This is made clearer by considering two beams, each of which will carry the same load. The fact that they are side by side will have no effect on what each will carry. It will be the same whether the beam is in two pieces or one piece. To double the width, therefore, doubles the capacity. Two inches in width added to a solid, dressed 6- by 10-inch girder, however, adds a little more than one third to its strength, since its actual width in the first place is only 5-1/2 inches.

DEPTH.–Doubling the depth of a girder much more than doubles the carrying capacity. Actually the increase is four-fold. In other words, a beam 3 inches wide and 12 inches deep will carry four times as much as one 3 inches wide and 6 inches deep. Therefore, as a general principle in the efficient use of material, to obtain greater carrying capacity, it is better to increase the depth of a beam than the width.

On the other hand, it is well to keep down the height of horizontal material in members; such as girders, joists, and the like. Too much depth in a girder, especially if placed under the joists, decreases headroom in the basement. It is desirable, therefore, to adopt any of the following courses rather than increase the girder depth to much more than 10 inches, or 12 inches at the most:

1. Increase the width.
2. Put in additional supports, thus reducing the girder span and permitting a smaller girder.
3. Use a stronger material.

Thoroughly dry lumber should always be used, especially if the girder is under joists.

Determining the Size of Girders

To determine the size of a girder, seven steps are necessary–

1. Find the distance between girder supports.
2. Find the "half widths."
3. Find the "total floor load" per square foot carried by joists and bearing partitions to the girder.
4. Find the load per linear foot on the girder.
5. Find the total load on the girder.
6. Select the material for the girder.
7. Find the proper size of the girder in the material chosen.

LENGTH OF GIRDER.–Before it is possible to determine the girder size the length of the girder between supports must be settled upon. This length will be determined by the spacing of supporting posts. These posts must be spaced according to some suitable division of the total length of the girder between walls. This may be determined at will, with due regard to the avoidance of excessive spans. To illustrate the method, reference may be made to figure 7-1, which is a building 35 feet wide by 31 feet 8 inches deep, with a first-floor arrangement as shown.

In such an arrangement, the partition between the living room and the dining room, with its extension between the front hall and kitchen, would probably be used as a bearing partition, and the girder should be located directly or nearly under it. This girder is 33 feet 8 inches long between basement walls. This can be divided into two, three, or four approximately equal parts of about 17 feet, 11 feet, or 8 feet 5 inches each, respectively.

As posts carry a relatively large part of the weight, and it is well to use short spans as a means of reducing the size of girders, it will be better in this case to use three posts, thus fixing the span at about 8 feet 5 inches center to center of posts.

Having determined the location of supports, the next step is to find out what proportion of the joist load the girder must carry. This involves the determination of what in the tables is called the "half width."

HALF WIDTHS.–Before discussing the half widths or considering the load on the girder it may be well to study a simple case.

Suppose two men were asked to pick up a plank 10 feet long, weighing 5 pounds for each foot of length, or 50 pounds in all. The two men

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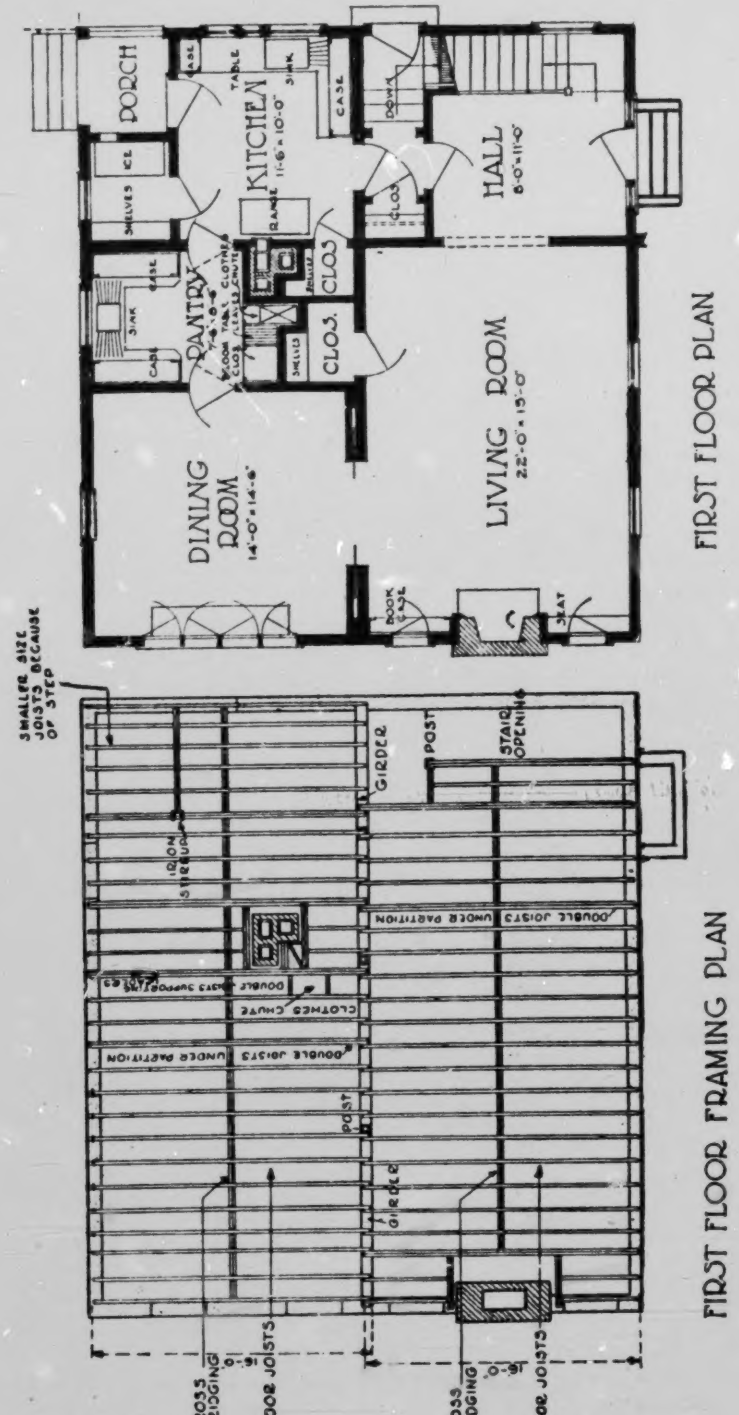
FIRST FLOOR PLAN
PORCH
KITCHEN
11'-6" x 10'-0"
TABLE
SINK
CASE
RANGE
ICE
SHELVES
PANTRY
7'-6" x 8'-6"
SINK
CASE
CLOS.
CLOS.
SHELVES
DOWN
HALL
8'-0" x 11'-0"
DINING ROOM
14'-0" x 14'-6"
LIVING ROOM
22'-0" x 15'-0"
BOOK CASE
SEAT
FIRST FLOOR FRAMING PLAN
SMALLER SIZE JOISTS BECAUSE OF STEP
IRON STIRRUP
GIRDER
POST
STAIR OPENING
DOUBLE JOISTS UNDER PARTITION
DOUBLE JOISTS SUPPORTING
CLOTHES CHUTE
DOUBLE JOISTS UNDER PARTITION
POST
GIRDER
CROSS BRIDGING
FLOOR JOISTS
16"-0
CROSS BRIDGING
FLOOR JOISTS
16"-0

Figure 7-1. —A first floor plan, showing location of posts, girders, and joists.

would bear the total weight between them and each would be lifting 25 pounds. (See figure 7-2.)

Now assume another 10-foot plank weighing the same. Suppose one of the men now holding the first plank is carrying one end of the second plank with a third man at its other end. (See figure 7-3.)

It will be seen that the man in the center carries half the weight of both planks and that the other two men divide the balance between them. In other words, the man at the center carries half the weight of each plank and each end man supports half a plank. A single girder running through the center of a building and supporting the inner ends of floor joists is in a position similar to the center man in the example and will take half the weight of every joist resting upon it. Thus the girder carries half the weight of the floor; and the foundation walls, supporting the outer ends of the joists, divide the other half between them.

It does not always happen, however, that the support is halfway between the outer walls. To analyze this condition, it may be well to return to the original example of the men and the planks. Assume that one plank is 8 feet long, and the other 12 feet long (figure 7-4), and that each weighs 5 pounds per foot. The total length of the two planks will be the same as before, or 20 feet, and the combined weight will be the same, or 100 pounds, with the 8-foot plank weighing 40 pounds and the 12-foot plank weighing 60 pounds. It should be clear that each of the men at the outer ends of the planks will carry half the weight of his respective plank, or 20 pounds for the short plank and 30 pounds for the longer. On the other hand, the man near the center will carry half the weight of each plank, or 20 pounds plus 30 pounds, a total of 50 pounds, which is exactly the same as in the previous illustration when the planks were of equal length. So the general statement may be made:

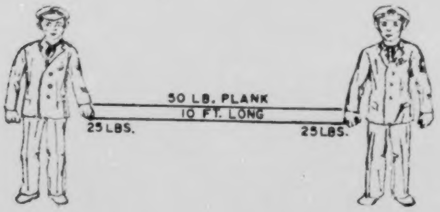

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Figure 7-2. —Each man carries 25 pounds.

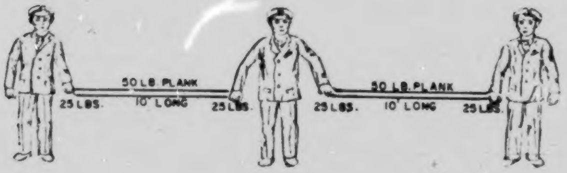
50 LB. PLANK
10' LONG
25 LBS.
25 LBS.
50 LB. PLANK
10' LONG
25 LBS.
25 LBS.

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Figure 7-3. —The man in the center carries one-half of the weight of each plank, or 50 pounds, whereas the men at the ends carry only one-half of one plank each, or 25 pounds.

A single girder running through a building, whether or not it be at the center, will carry half the weight of the floor between it and the adjacent walls or girders.

This statement may be modified slightly to include the numerous conditions ordinarily met with in building as, for example, where there are two or more girders.

GENERAL RULE FOR HALF WIDTHS: A girder will carry the weight of the floor on each side to the midpoint of the joists which rest upon it. (See following discussion for special cases.)

This statement assumes that joists are butted or lapped over the girder. Butted or lapped over the girder, fully loaded joists tend to sag between supports, as shown in exaggerated fashion in figure 7-5.

Under such conditions there is no resistance to bending over the girder because of being merely butted, or at best, lapped and spiked.

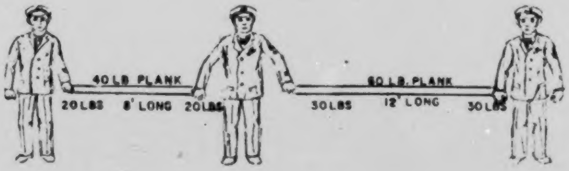

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Figure 7-4. —The man near the center carries one-half of the weight of each plank, in this case a total of 50 pounds.

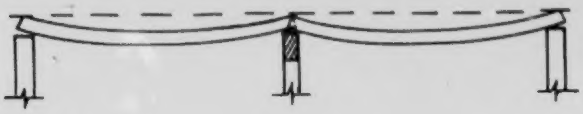

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Figure 7-5. —Joist action when butted or lapped over a girder.

Suppose, however, the joists were continuous. Under load they would tend to assume the shape indicated in figure 7-6.

Being in one piece, they offer resistance to bending over the center support, and the girder is forced to carry a larger proportion of the load than if the joists were cut. The proportion actually taken can be found by formulas worked out by civil engineers. The method is complicated and involves higher mathematics, but the results may be stated as follows: If the girder is at the midpoint of continuous joists it will take five-eighths instead of one-half of the floor load.

NOTE: If the girder is not located midway between adjacent supports the determination of its load is further complicated. As the girder support moves to one side, the proportion of the floor load carried gradually decreases from five-eights toward one-half. As it is seldom economical to put the girder far off center for continuous joists, all girders supporting continuous joists should be designed to support five-eighths of the total floor load of adjacent spans.

The following may be used as a working rule for half widths:

To ascertain the half width for a girder, find the distance from the centerline of the girder to the nearest joist support on one side (which distance is generally known as the joist span). Add to this figure the corresponding span or distance from the girder to the nearest girder or wall on the other side. One-half of the total corresponds to the "half width," provided the joists are lapped or butted over the girder. If the joists are continuous, five-eights or the total corresponds to the "half width."

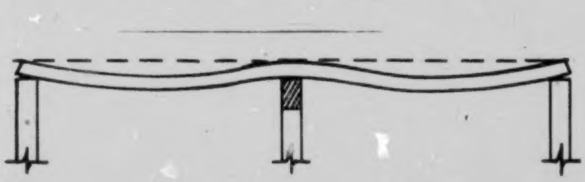

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Figure 7-6. —Joist action when continuous over girders.

To show the application of this rule, the following examples are given:

Example 1.—This is the simplest case. (See figure 7-7.) There is a single girder running the length of the building. The heavy line shows the position of the girder and the light lines running at right angles thereto indicate the joists which rest upon it. The joist spans—that is, the distances to the nearest joint supports on either side of this girder—are 7 and 13 feet, a total of 20 feet. Half of this total, or 10 feet, is the "half width" for this girder, if the joists are cut. If the joists are continuous, the "half width" is five-eighths of 20 feet, or 12-1/2 feet.

Example 2.—Here the problem is complicated by the presence of two girders. (See figure 7-8.) In such cases, each girder must be taken separately. Applying the rule to girder A, the joist spans on either side are 13 and 7 feet, respectively, or a total of 20 feet. Half of this, or

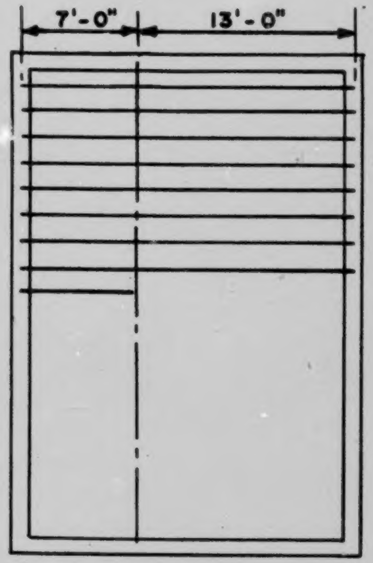

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Figure 7-7. —Example 1: Single girder.

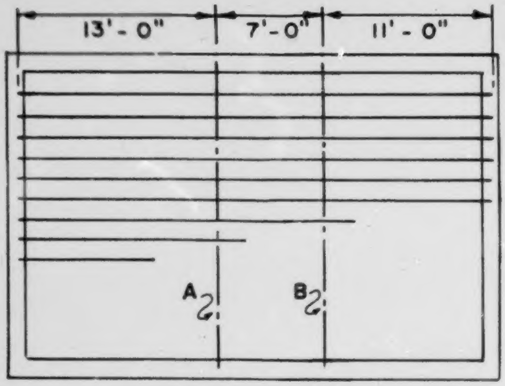

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Figure 7-8. –Example 2: Two girders.

10 feet for cut joists, is the half width for this girder.

In the case of girder B, the joist spans are 7 and 11 feet, or a total of 18 feet. The figure corresponding to the half width for girder B is 9 feet.

TOTAL FLOOR LOAD.–The method for calculating the total floor load per square foot carried by joists and bearing partitions to the girder is illustrated in figure 7-9. The live loads specified also form the basis for determining the size of joists; and while larger than commonly occur, are used to provide adequate stiffness in the floor for all occasions. It may be possible that the maximum load provided for will never be applied, but consideration must be given to the possibility of crowded rooms and unusual loading situations, as when furniture is moved to the center of the room to permit painting or papering. When calculating loads for small-house framing, you will find the information given in figure 7-9 valuable.

Assume that figure 7-9 represents an end view of the building whose dimensions have been under discussion and is shown in figure 7-1. The girder being studied carries the first floor joist load. The bearing partition above, which rests directly upon the girder, will carry the second floor joist load also down to the girder. Hence, the girder will carry the weight of the second floor in addition to the first. Similarly, there is a bearing partition on the second floor which carries the second floor ceiling, attic, and roof loads. Thus the girder must carry not only the first floor, but the second floor, attic, and roof.

NOTE: In some buildings the roof is framed so that the roof loads are carried entirely by the outside walls. In this case, no allowance would be made for roof loads when calculating total floor load to be carried by the girder. For this reason a plan should be carefully studied, and framing methods analyzed, to determine just what loads are carried through the bearing partitions to the girder.

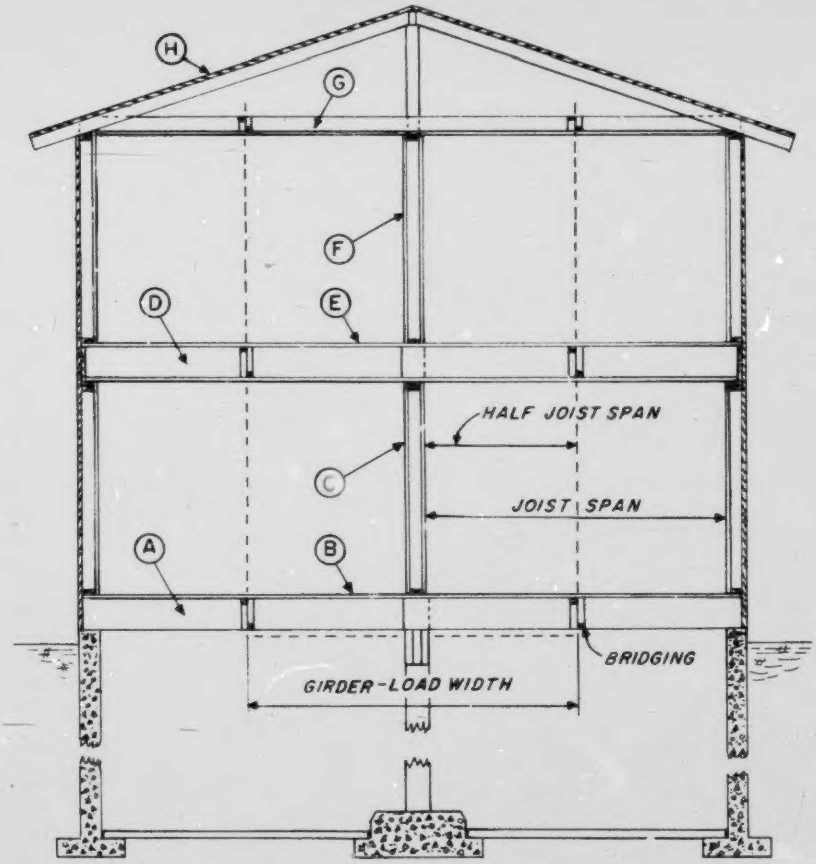
Using the live and dead load figures given, the total combined square foot floor load to be carried by the girder in figure 7-9 may be represented as follows:

(A)	Dead load of first floor	10
(B)	Live load on first floor..........	40
(C)	Dead load of partitions	10
(D)	Dead load of second floor	20
(E)	Live load on second floor........	40
(F)	Dead load of partitions	10
(G)	Live load on attic floor	20
	Dead load of attic floor	10
(H)	Dead and live load of light roof ...	20
	Total	180

The minimum floor load to be allowed for the girder under discussion is 180 pounds per square foot. This is based on the assumption that there is no attic flooring, and that the ceiling of the basement is not plastered.

LOAD PER LINEAR FOOT ON THE GIRDER.–To get the load per linear foot of girder, the total live and dead load per square foot for all floors supported, for the roof if it rests on a bearing partition, and for the bearing partitions, is multiplied by the half width, previously determined. Table 7-1 gives loads per linear foot on girders for various half widths and types of buildings, as explained previously in this chapter. In the left-hand column are figures for various total loads per square foot. Each column is for a different half width. The table shows the total load per linear foot on the girder, the figures being the product of the total square foot load by the half width.

The table shows that for a half width of 15 feet (5 feet + 10 feet) and a total square-foot



(A) DEAD LOAD OF FIRST FLOOR = 10 LBS PER SQ FT. DEAD LOAD OF FIRST FLOOR WITH BASEMENT CEILING PLASTERED = 20 LBS PER SQ FT.

(B) LIVE LOAD ON FIRST FLOOR = 40 LBS PER SQ FT UNLESS OTHERWISE SPECIFIED BY LOCAL BUILDING CODE REQUIREMENTS.

(C) DEAD LOAD OF PARTITIONS = 10 LBS PER SQ FT UNLESS OTHERWISE SPECIFIED.

(D) DEAD LOAD ON SECOND FLOOR = 20 LBS PER SQ FT.

(E) LIVE LOAD ON SECOND FLOOR = 40 LBS PER SQ FT UNLESS OTHERWISE SPECIFIED BY LOCAL BUILDING CODE REQUIREMENTS.

(F) DEAD LOAD OF PARTITIONS = 10 LBS PER SQ FT UNLESS OTHERWISE SPECIFIED.

(G) LIVE LOAD ON ATTIC FLOOR = 20 LBS PER SQ FT WHEN USED FOR STORAGE ONLY. DEAD LOAD OF ATTIC FLOOR NOT FLOORED = 10 LBS PER SQ FT. DEAD LOAD OF ATTIC FLOOR WHEN FLOORED = 20 LBS PER SQ FT WHEN USED FOR STORAGE ONLY.

(H) ROOF OF LIGHT CONSTRUCTION, INCLUDING BOTH LIVE AND DEAD LOADS = 20 LBS PER SQ FT. ROOF OF MEDIUM CONSTRUCTION WITH LIGHT SLATE OR ASBESTOS ROOFING, INCLUDING BOTH LIVE AND DEAD LOADS = 30 LBS PER SQ FT. ROOF OF HEAVY CONSTRUCTION WITH HEAVY SLATE OR TILE ROOFING, INCLUDING BOTH LIVE AND DEAD LOADS = 40 LBS PER SQ FT. NOTE: LOCAL BUILDING CODE REQUIREMENTS SHOULD BE CONSULTED AS THEY MAY SPECIFY OTHER MINIMUM LOAD VALUES.

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Figure 7-9. —Calculating "total floor load" per square foot carried by joists and bearing partitions to the girder.

Table 7-1.–Girder Loads Per Linear Foot: Total Load Per Linear Foot on the Girder of Various "Half-Widths" For Various Total Floor Loadings

Total square-foot floor load	Total girder load per linear foot by "half widths"										
	5	6	7	8	9	10	12	14	16	18	20
10	50	60	70	80	90	100	120	140	160	180	200
20	100	120	140	160	180	200	240	280	320	360	400
30	150	180	210	240	270	300	360	420	480	540	600
40	200	240	280	320	360	400	480	560	640	720	800
50	250	300	350	400	450	500	600	700	800	900	1, 000
60	300	360	420	480	540	600	720	840	960	1, 080	1, 200
70	350	420	490	560	630	700	840	980	1, 120	1, 260	1, 400
80	400	480	560	640	720	800	960	1, 120	1, 280	1, 440	1, 600
90	450	540	630	720	810	900	1, 080	1, 260	1, 440	1, 620	1, 800
100	500	600	700	800	900	1, 000	1, 200	1, 400	1, 600	1, 800	2, 000
110	550	660	770	880	990	1, 100	1, 320	1, 540	1, 760	1, 980	2, 200
120	600	720	840	960	1, 080	1, 200	1, 440	1, 680	1, 920	2, 160	2, 400
130	650	780	910	1, 040	1, 170	1, 300	1, 560	1, 820	2, 080	2, 340	2, 600
140	700	840	980	1, 120	1, 260	1, 400	1, 680	1, 960	2, 240	2, 520	2, 800
150	750	900	1, 050	1, 200	1, 350	1, 500	1, 800	2, 100	2, 400	2, 700	3, 000
160	800	960	1, 120	1, 280	1, 440	1, 600	1, 920	2, 240	2, 560	2, 880	3, 200
170	850	1, 020	1, 190	1, 360	1, 530	1, 700	2, 040	2, 380	2, 720	3, 060	3, 400
180	900	1, 080	1, 260	1, 440	1, 620	1, 800	2, 160	2, 520	2, 880	3, 240	3, 600
190	950	1, 140	1, 330	1, 520	1, 710	1, 900	2, 280	2, 660	3, 040	3, 420	3, 800
200	1, 000	1, 200	1, 400	1, 600	1, 800	2, 000	2, 400	2, 800	3, 200	3, 600	4, 000
210	1, 050	1, 260	1, 470	1, 680	1, 890	2, 100	2, 520	2, 940	3, 360	3, 780	4, 200
220	1, 100	1, 320	1, 540	1, 760	1, 980	2, 200	2, 640	3, 080	3, 520	3, 960	4, 400

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floor load of 180 pounds, the load on the girder is 2,700 pounds per foot of length. In this case, the load represents the combined weights of strips of the first, second, and attic floors measured 1 foot along the girder and 15 feet across it, carried by each foot of the girder. It will be noted that the half widths are given in feet. In cases where half widths are not in even feet, the nearest whole foot should be used.

TOTAL LOAD ON THE GIRDER.–If the load upon the girder is 2,700 pounds for each foot of length, as determined in the usual way, the total load which it must carry is that figure multiplied by the distance in feet between girder supports. The total load per foot in this case is 2,700 pounds, which multiplied by the length of the girder, or 8 feet 5 inches, if it is assumed that posts are equally spaced, is 22,750 pounds. This is the total load that the girder must carry. As this load does not occur at any one point, but is, for all practical purposes, spread equally over the whole length, it is what is termed a "uniformly distributed" load.

MATERIAL FOR THE GIRDER.–At this point it must be decided whether the girder is to be of wood or steel. If of wood, the kind or species must be decided; and it also must be decided whether to use a built-up or solid member.

In table 7-2 is given a list of various softwoods used for building construction, with allowable unit working stresses for each species and grade. The species in the upper half of the list are manufactured in structural grades as shown. Definite working stresses have been assigned to all these grades by the manufacturers.

Under the heading "Extreme fiber in bending" the first column gives working stresses in bending for joists up to four inches in thickness. The second column shows stresses for timbers five inches and over in thickness. Knowing the species to be used, pick out the corresponding bending stress. Next select from tables 7-3, 7-4, 7-5, and 7-6, the table based on the same or next smaller working stress.

Tables 7-3 through 7-6 give the total safe loads for different solid-wood girder sizes and

Table 7-2. —Allowable Unit Stresses For Structural Lumber and Timber

[All sizes; dry locations][1]

WORKING STRESSES FOR MANUFACTURERS' ASSOCIATION STANDARD COMMERCIAL GRADES

Species of timber	Grade	Allowable unit stress in pounds per square inch		
		Extreme fiber in bending		Modulus of elasticity
		Joist and plank sizes; 4 inches and less in thickness	Beam and stringer sizes; 5 inches and thicker	
Douglas fir, coast region	Dense superstructural	2,000	2,000	1,600,000
	Superstructural and dense structural	1,800	1,800	1,600,000
	Structural	1,600	1,600	1,600,000
	Common structural	1,200	1,400	1,600,000
Douglas fir, inland empire	Dense superstructural *	2,000	2,000	1,600,000
	Dense structural *	1,800	1,800	1,600,000
	No. 1 common dimension and timbers	1,135	1,135	1,500,000
Larch, western	No. 1 common dimension and timbers	1,135	1,135	1,300,000
Pine, southern yellow	Extra dense select structural	2,300	2,300	1,600,000
	Select structural	2,000	2,000	1,600,000
	Extra dense heart	2,000	2,000	1,600,000
	Dense heart	1,800	1,800	1,600,000
	Structural square edge and sound	1,600	1,600	1,600,000
	Dense No. 1 common	1,200	1,200	1,600,000
Redwood	Superstructural	2,133	1,707	1,200,000
	Prime structural	1,707	1,494	1,200,000
	Select structural	1,280	1,322	1,200,000
	Heart structural	1,024	1,150	1,200,000

* When graded the same as corresponding grade of coast region Douglas fir.

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spans, with working stresses of 1,600, 1,400, 1,200, and 900 pounds per square inch, respectively. These working stresses cover the range in values specified in most building codes. Where girders larger than those shown in tables are found necessary, design considerations will usually be such as to make it desirable to consult a competent civil engineer or architect. It is assumed when the depth of the girder is greater than one-twelfth of the span, loads will be limited by horizontal shear strength instead of bending strength.

For example, if No. 1 common Southern yellow pine is to be used, the value given under "Extreme fiber in bending" is 1,200 pounds per square inch. Hence, use table 7-5 based on 1,200 pounds per square inch. Similarly if a structural grade of Douglas fir is to be used with bending stress of 1,800 pounds per square inch, table 7-3 based on 1,600 pounds per square inch should be used.

SIZE OF WOOD GIRDER.–If the total load on the girder, the span, and the strength or allowable working stress of the lumber to be used are known, it is possible by engineering formula to compute the necessary size of the girder. This, however, has been worked out and is given in the tables which show the maximum allowable loads on beams of different sizes and for various spans. The size needed will naturally vary with the species and grade used. The girder may be one solid timber or of several pieces spiked together, but if a built-up girder is used, care should be taken to use the percentage figures applying to built-up girders, which allow for the lesser thickness of dressed material. A built-up girder is as satisfactory as a solid one. In fact, a built-up girder may be better, as it affords an opportunity to select and arrange the material for the best possible results.

In tables 7-3, 7-4, and 7-5 are shown zigzag lines starting at the left at the top and ending at the right at the bottom of the tables. Loads

Table 7-3. —Solid Wood Girders: Allowable Fiber Stress 1,600 Pounds Per Square Inch; Modulus of Elasticity, E-1,600,000

[Allowable uniformly distributed loads for solid wood girders and beams in pounds computed for actual dressed sizes]

Solid dressed sizes	Span in feet														
	4, 5, 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
3 by 6	2,435	2,078	1,812	1,602	1,434	1,296	1,180	1,080	995	921	855	796	744	696	654
4 by 6	3,366	2,875	2,505	2,213	1,981	1,791	1,630	1,493	1,375	1,272	1,183	1,101	1,030	965	905
6 by 6	4,885	4,165	3,633	3,211	2,873	2,596	2,363	2,166	1,995	1,845	1,714	1,595	1,492	1,396	1,310
2 by 8	2,145	2,145	2,016	1,785	1,600	1,446	1,320	1,213	1,119	1,038	967	902	846	795	749
3 by 8	3,460	3,460	3,233	2,864	2,567	2,322	2,118	1,944	1,794	1,663	1,549	1,445	1,354	1,263	1,197
4 by 8	4,770	4,770	4,470	3,960	3,549	3,212	2,930	2,690	2,484	2,304	2,145	2,002	1,878	1,765	1,662
6 by 8	7,260	7,260	6,783	6,008	5,386	4,875	4,446	4,082	3,768	3,495	3,255	3,039	2,850	2,678	2,522
8 by 8	9,880	9,880	9,247	8,193	7,344	6,646	6,063	5,566	5,139	4,766	4,437	4,143	3,886	3,651	3,438
2 by 10	2,700	2,700	2,700	2,700	2,564	2,323	2,120	1,949	1,802	1,672	1,561	1,459	1,371	1,290	1,217
3 by 10	4,370	4,370	4,370	4,370	4,139	3,749	3,424	3,146	2,908	2,699	2,517	2,353	2,210	2,079	1,961
4 by 10	6,035	6,035	6,035	6,035	5,719	5,177	4,731	3,348	4,019	3,732	3,480	3,255	3,057	2,878	2,715
6 by 10	9,160	9,160	9,160	9,160	8,680	7,862	7,179	6,598	6,100	5,664	5,283	4,940	4,641	4,368	4,121
8 by 10	12,500	12,500	12,500	12,500	11,835	10,720	9,790	9,000	8,318	7,724	7,205	6,738	6,329	5,957	5,620
10 by 10	15,805	15,805	15,805	15,805	14,992	13,581	12,401	11,399	10,536	9,785	9,126	8,535	8,017	7,546	7,120
2 by 12	3,265	3,265	3,265	3,265	3,265	3,265	3,122	2,871	2,657	2,469	2,305	2,158	2,028	1,911	1,806
3 by 12	5,260	5,260	5,260	5,260	5,260	5,260	5,037	4,633	4,285	3,982	3,716	3,478	3,270	3,081	2,909
4 by 12	7,270	7,270	7,270	7,270	7,270	7,270	6,963	6,404	5,925	5,507	5,140	4,813	4,525	4,265	4,029
6 by 12	11,050	11,050	11,050	11,050	11,050	11,050	10,566	9,718	8,991	8,357	7,802	7,303	6,869	6,472	6,115
8 by 12	15,050	15,050	15,050	15,050	15,050	15,050	14,408	13,252	12,260	11,396	10,638	9,959	9,366	8,826	8,337
10 by 12	19,080	19,080	19,080	19,080	19,080	19,080	18,249	16,786	15,529	14,435	13,475	12,615	11,863	11,180	10,560
12 by 12	23,130	23,130	23,130	23,130	23,130	23,130	22,090	20,320	18,797	17,474	16,311	15,270	14,360	13,533	12,783
2 by 14	4,115	4,115	4,115	4,115	4,115	4,115	4,115	4,115	3,669	3,412	3,186	2,885	2,808	2,587	2,502
3 by 14	6,165	6,165	6,165	6,165	6,165	6,165	6,165	6,165	5,931	5,515	5,150	4,825	4,540	4,281	4,046
4 by 14	8,510	8,510	8,510	8,510	8,510	8,510	8,510	8,510	8,200	7,626	7,123	6,674	6,280	5,923	5,600
6 by 14	12,930	12,930	12,930	12,930	12,930	12,930	12,930	12,930	12,440	11,571	10,810	10,125	9,530	8,987	8,498
8 by 14	17,630	17,630	17,630	17,630	17,630	17,630	17,630	17,630	16,964	15,780	14,740	13,809	12,996	12,258	11,590
10 by 14	22,335	22,335	22,335	22,335	22,335	22,335	22,335	22,335	21,487	19,986	18,670	17,490	16,460	15,524	14,676
12 by 14	27,040	27,040	27,040	27,040	27,040	27,040	27,040	27,040	26,010	24,194	22,600	21,171	19,925	18,792	17,766
14 by 14	31,760	31,760	31,760	31,760	31,760	31,760	31,760	31,760	30,512	28,390	26,530	24,860	23,390	22,040	20,838

Built-up girders

Multiply above figures by 0.897 when 4-inch girder is made up of two 2-inch pieces.
.887 when 6-inch girder is made up of three 2-inch pieces.
.867 when 8-inch girder is made up of four 2-inch pieces.
.856 when 10-inch girder is made up of five 2-inch pieces.

Note.—Built-up girders of dressed lumber will carry somewhat smaller loads than solid girders; that is, two 2-inch dressed planks will equal only 3¼, whereas dressed 4-inch lumber will equal 3⅝. It is, therefore, necessary to multiply by the above figures in order to compute the loads for built-up girders.

117.384

Table 7-4. —Solid Wood Girders: Allowable Fiber Stress 1,400 Pounds Per Square Inch

[Allowable uniformly distributed loads for wood girders and beams in pounds computed for actual dressed sizes]

Solid dressed sizes	Span in feet														
	4, 5, 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2 by 6	1,318	1,124	979	865	774	699	636	582	536	495	459	427	399	372	349
3 by 6	2,127	1,816	1,581	1,397	1,249	1,128	1,026	938	863	798	740	688	641	599	561
4 by 6	2,938	2,507	2,184	1,930	1,726	1,559	1,418	1,297	1,194	1,102	1,023	952	888	831	777
6 by 6	4,263	3,638	3,168	2,800	2,504	2,260	2,055	1,881	1,731	1,599	1,483	1,379	1,286	1,202	1,126
2 by 8	1,865	1,865	1,780	1,558	1,395	1,260	1,150	1,055	973	902	839	783	733	687	646
3 by 8	3,020	3,020	2,824	2,500	2,238	2,024	1,845	1,692	1,560	1,444	1,343	1,253	1,172	1,100	1,034
4 by 8	4,165	4,165	3,904	3,456	3,906	2,800	2,552	2,342	2,160	2,002	1,862	1,737	1,626	1,528	1,435
6 by 8	6,330	6,330	5,924	5,244	4,698	4,250	3,873	3,553	3,277	3,037	2,825	2,636	2,468	2,315	2,178
8 by 8	8,630	8,630	8,078	7,151	6,406	5,793	5,281	4,845	4,469	4,141	3,851	3,595	3,365	3,157	2,969
2 by 10	2,360	2,360	2,360	2,360	2,237	2,028	1,848	1,699	1,569	1,455	1,356	1,268	1,190	1,118	1,054
3 by 10	3,810	3,810	3,810	3,810	3,612	3,271	2,984	2,740	2,531	2,348	2,267	2,045	1,917	1,803	1,698
4 by 10	5,265	5,265	5,265	5,265	4,992	4,520	4,125	3,788	3,500	3,248	3,026	2,830	2,653	2,496	2,352
6 by 10	7,990	7,990	7,990	7,990	7,576	6,860	6,261	5,751	5,312	4,929	4,593	4,294	4,029	3,787	3,571
8 by 10	10,920	10,920	10,920	10,920	10,330	9,351	8,537	7,841	7,244	6,922	6,264	5,857	5,493	5,165	4,868
10 by 10	13,825	13,825	13,825	13,825	13,085	11,849	10,813	9,933	9,176	8,815	7,934	7,419	6,958	6,543	6,168
2 by 12	2,845	2,845	2,845	2,845	2,845	2,845	2,724	2,503	2,315	2,150	2,006	1,878	1,763	1,660	1,567
3 by 12	4,590	4,590	4,590	4,590	4,590	4,590	4,394	4,039	3,734	3,468	3,234	3,026	2,842	2,675	2,524
4 by 12	6,350	6,350	6,350	6,350	6,350	6,350	6,075	5,585	5,165	4,797	4,474	4,189	3,933	3,705	3,496
6 by 12	9,640	9,640	9,640	9,640	9,640	9,640	9,220	8,475	7,837	7,280	6,791	6,357	5,970	5,622	5,307
8 by 12	13,160	13,160	13,160	13,160	13,160	13,160	12,570	11,556	10,685	9,926	9,260	8,669	8,141	7,666	7,237
10 by 12	16,670	16,670	16,670	16,670	16,670	16,670	15,923	14,638	13,536	12,573	11,728	10,980	10,311	9,710	9,166
12 by 12	20,170	20,170	20,170	20,170	20,170	20,170	19,274	17,709	16,384	15,220	14,197	13,291	12,482	11,753	11,096
2 by 14	3,595	3,595	3,595	3,595	3,595	3,595	3,595	3,595	3,189	2,973	2,776	2,490	2,413	2,301	2,173
3 by 14	5,365	5,365	5,365	5,365	5,365	5,365	5,365	5,365	5,171	4,805	4,485	4,202	3,949	3,721	3,514
4 by 14	7,420	7,420	7,420	7,420	7,420	7,420	7,420	7,420	7,151	6,646	6,225	5,814	5,465	5,150	4,876
6 by 14	11,290	11,290	11,290	11,290	11,290	11,290	11,290	11,290	10,849	10,086	9,415	8,821	8,292	7,814	7,384
8 by 14	15,360	15,360	15,360	15,360	15,360	15,360	15,360	15,360	14,796	13,754	12,840	12,030	11,307	10,658	10,071
10 by 14	19,465	19,465	19,465	19,465	19,465	19,465	19,465	19,465	18,740	17,420	16,261	15,236	14,321	13,498	12,755
12 by 14	23,590	25,590	23,590	23,590	23,590	23,590	23,590	23,590	22,685	21,088	19,685	18,445	17,236	16,340	15,440
14 by 14	27,690	27,690	27,690	27,690	27,690	27,690	27,690	27,690	26,630	24,754	23,108	21,652	20,350	20,142	18,125

Built-up girders

Multiply above figures by 0.897 when 4-inch girder is made up of two 2-inch pieces.
.887 when 6-inch girder is made up of three 2-inch pieces.
.867 when 8-inch girder is made up of four 2-inch pieces.
.856 when 10-inch girder is made up of five 2-inch pieces.

NOTE.—Built-up girders of dressed lumber will carry somewhat smaller loads than solid girders; that is, two 2-inch dressed planks will equal only 3¼, whereas dressed 4-inch lumber will equal 3⅝. It is, therefore, necessary to multiply by the above figures in order to compute the loads for built-up girders.

117.385

Table 7-5. —Solid Wood Girders: Allowable Fiber Stress 1,200 Pounds Per Square Inch

[Allowable uniformly distributed loads for solid wood girders and beams in pounds computed for actual dressed sizes]

Solid dressed sizes	Span in feet														
	4, 5, 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2 by 6	1,127	961	837	738	660	595	541	494	454	419	388	360	335	312	292
3 by 6	1,820	1,552	1,351	1,192	1,065	960	872	796	731	675	625	580	539	502	469
4 by 6	2,514	2,144	1,866	1,647	1,471	1,327	1,206	1,102	1,012	933	864	802	747	697	650
6 by 6	3,650	3,111	2,708	2,389	2,134	1,924	1,747	1,597	1,467	1,352	1,252	1,161	1,081	1,007	941
2 by 8	1,605	1,605	1,503	1,331	1,191	1,075	980	898	827	766	712	662	619	580	544
3 by 8	2,580	2,580	2,414	2,135	1,911	1,726	1,572	1,439	1,325	1,225	1,139	1,060	990	927	870
4 by 8	3,570	3,570	3,340	2,953	2,643	2,388	2,175	1,993	1,836	1,700	1,590	1,472	1,375	1,288	1,210
6 by 8	5,420	5,420	5,064	4,481	4,011	3,625	3,300	3,025	2,786	2,579	2,396	2,232	2,086	1,953	1,831
8 by 8	7,390	7,390	6,905	6,110	5,464	4,941	4,500	4,125	3,799	3,516	3,265	3,043	2,845	2,664	2,500
2 by 10	2,020	2,020	2,020	2,020	1,912	1,730	1,578	1,449	1,336	1,238	1,153	1,077	1,009	946	891
3 by 10	3,255	3,255	3,255	3,255	3,088	2,792	2,546	2,336	2,152	1,997	1,859	1,735	1,624	1,525	1,435
4 by 10	4,500	4,500	4,500	4,500	4,267	3,864	3,520	3,230	2,981	2,763	2,572	2,402	2,249	2,113	1,988
6 by 10	6,830	6,830	6,830	6,830	6,473	5,860	5,341	4,902	4,524	4,193	3,904	3,647	3,416	3,206	3,020
8 by 10	9,320	9,320	9,320	9,320	8,827	7,980	7,284	6,685	6,179	5,719	5,324	4,972	4,657	4,374	4,116
10 by 10	11,795	11,795	11,795	11,795	11,181	10,110	9,226	8,468	7,815	7,245	6,744	6,299	5,900	5,540	5,215
2 by 12	2,435	2,435	2,435	2,435	2,435	2,435	2,328	2,136	1,973	1,832	1,708	1,597	1,497	1,410	1,328
3 by 12	3,920	3,920	3,920	3,920	3,920	3,920	3,754	3,446	3,183	2,953	2,752	2,572	2,413	2,269	2,138
4 by 12	5,430	5,430	5,430	5,430	5,430	5,430	5,191	4,766	4,393	4,087	3,809	3,553	3,341	3,143	2,964
6 by 12	8,250	8,250	8,250	8,250	8,250	8,250	7,870	7,232	6,682	6,202	5,781	5,407	5,072	4,770	4,499
8 by 12	11,240	11,240	11,240	11,240	11,240	11,240	10,733	9,862	9,121	8,456	7,783	7,374	6,916	6,506	6,131
10 by 12	14,250	14,250	14,250	14,250	14,250	14,250	13,597	12,491	11,541	10,711	9,985	9,338	8,760	8,240	7,769
12 by 12	17,240	17,240	17,240	17,240	17,240	17,240	16,460	15,121	13,960	12,967	12,086	11,304	10,605	9,974	9,404
2 by 14	3,065	3,065	3,065	3,065	3,065	3,065	3,065	3,065	2,729	2,534	2,366	2,212	2,076	1,954	1,845
3 by 14	4,600	4,600	4,600	4,600	4,600	4,600	4,600	4,600	4,412	4,097	3,825	3,577	3,358	3,161	2,984
4 by 14	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,102	5,668	5,288	4,950	4,648	4,377	4,132
6 by 14	9,630	9,630	9,630	9,630	9,630	9,630	9,630	9,630	9,258	8,601	8,020	7,511	7,054	6,642	6,270
8 by 14	13,140	13,140	13,140	13,140	13,140	13,140	13,140	13,140	12,628	11,730	10,942	10,244	9,619	9,058	8,552
10 by 14	16,640	16,640	16,640	16,640	16,640	16,640	16,640	16,640	16,002	14,854	13,860	12,975	12,183	11,472	10,830
12 by 14	20,140	20,140	20,140	20,140	20,140	20,140	20,140	20,140	19,167	17,982	16,780	15,706	14,748	13,887	13,110
14 by 14	23,640	23,640	23,640	23,640	23,640	23,640	23,640	23,640	22,742	21,120	19,690	18,440	17,310	16,370	15,388

Built-up girders

Multiply above figures by 0.897 when 4-inch girder is made up of two 2-inch pieces.
.887 when 6-inch girder is made up of three 2-inch pieces.
.867 when 8-inch girder is made up of four 2-inch pieces.
.856 when 10-inch girder is made up of five 2-inch pieces.

NOTE.—Built-up girders of dressed lumber will carry somewhat smaller loads than solid girders, that is, two 2-inch dressed planks will equal only 3¼, whereas dressed 4-inch lumber will equal 3⅝. It is, therefore, necessary to multiply by the above figures in order to compute the loads for built-up girders.

117.386

Table 7-6. —Solid Wood Girders: Allowable Fiber Stress 900 Pounds Per Square Inch

[Allowable uniformly distributed loads for solid wood girders and beams in pounds computed for actual dressed sizes]

Solid dressed sizes	Span in feet														
	4, 5, 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2 by 6	842	717	623	548	489	439	398	362	332	304	281	259	240	222	207
3 by 6	1,359	1,159	1,005	884	788	708	642	583	534	490	452	417	385	357	331
4 by 6	1,877	1,600	1,390	1,223	1,089	980	887	808	739	678	625	577	534	496	459
6 by 6	2,723	2,319	2,013	1,773	1,579	1,430	1,285	1,170	1,071	983	905	835	773	715	663
2 by 8	1,195	1,195	1,123	991	885	796	725	663	608	561	520	492	449	418	392
3 by 8	1,928	1,928	1,801	1,589	1,419	1,278	1,162	1,061	974	898	831	771	717	668	624
4 by 8	2,666	2,666	2,488	2,198	1,963	1,770	1,610	1,470	1,351	1,247	1,154	1,072	997	931	869
6 by 8	4,045	4,045	3,781	3,335	2,980	2,687	2,441	2,222	2,050	1,891	1,751	1,626	1,513	1,411	1,318
8 by 8	5,515	5,515	5,148	4,547	4,062	3,663	3,328	3,043	2,795	2,578	2,386	2,216	2,063	1,924	1,797
2 by 10	1,504	1,504	1,504	1,504	1,423	1,286	1,170	1,072	987	912	947	789	737	689	647
3 by 10	2,428	2,428	2,428	2,428	2,296	2,074	1,888	1,728	1,591	1,472	1,365	1,271	1,185	1,109	1,040
4 by 10	3,357	3,357	3,357	3,357	3,174	2,864	2,611	2,391	2,202	2,036	1,891	1,761	1,644	1,539	1,443
6 by 10	5,095	5,095	5,095	5,095	4,818	4,352	3,962	3,629	3,342	3,092	2,870	2,673	2,496	2,336	2,191
8 by 10	6,947	6,947	6,947	6,947	6,570	5,933	5,403	4,949	4,558	4,215	3,914	3,645	3,404	3,186	2,989
10 by 10	8,800	8,800	8,800	8,800	8,523	7,518	6,844	6,270	5,774	5,340	4,958	4,617	4,312	4,037	3,786
2 by 12	1,812	1,812	1,812	1,812	1,812	1,812	1,729	1,585	1,462	1,354	1,260	1,176	1,099	1,032	970
3 by 12	2,918	2,918	2,918	2,918	2,918	2,918	2,787	2,556	2,357	2,182	2,029	1,890	1,770	1,660	1,560
4 by 12	4,038	4,038	4,038	4,038	4,038	4,038	3,856	3,536	3,262	3,022	2,810	2,623	2,454	2,303	2,165
6 by 12	6,130	6,130	6,130	6,130	6,130	6,130	5,852	5,367	4,950	4,587	4,266	3,980	3,725	3,495	3,286
8 by 12	8,360	8,360	8,360	8,360	8,360	8,360	7,978	7,319	6,750	6,253	5,818	5,427	5,080	4,766	4,482
10 by 12	10,595	10,595	10,595	10,595	10,595	10,595	10,107	9,270	8,550	7,920	7,367	6,875	6,434	6,037	5,674
12 by 12	12,822	12,822	12,822	12,822	12,822	12,822	12,233	11,221	10,349	9,588	8,918	8,321	7,788	7,308	6,870
2 by 14	2,278	2,278	2,278	2,278	2,278	2,278	2,278	2,278	2,876	1,875	1,746	1,631	1,628	1,434	1,350
3 by 14	3,409	3,409	3,409	3,409	3,409	3,409	3,409	3,409	3,273	3,035	2,825	2,638	2,472	2,322	2,186
4 by 14	4,717	4,717	4,717	4,717	4,717	4,717	4,717	4,717	4,530	4,200	3,918	3,654	3,425	3,219	3,031
6 by 14	7,157	7,517	7,157	7,157	7,157	7,157	7,157	7,157	6,872	6,373	5,930	5,545	5,198	4,884	4,595
8 by 14	9,751	9,751	9,751	9,751	9,751	9,751	9,751	9,751	9,371	8,692	8,002	7,563	7,088	6,663	6,274
10 by 14	12,365	12,635	12,365	12,365	12,365	12,365	12,365	12,365	11,869	11,008	10,250	9,578	8,977	8,436	7,943
12 by 14	14,965	14,965	14,965	14,965	14,965	14,965	14,965	14,965	14,367	13,326	12,410	11,595	10,867	10,212	9,618
14 by 14	17,567	17,567	17,567	17,567	17,567	17,567	17,567	17,567	16,872	15,646	14,580	13,620	12,760	11,990	11,288

Built-up girders

Multiply above figures by 0.897 when 4-inch girder is made up of two 2-inch pieces.
.887 when 6-inch girder is made up of three 2-inch pieces.
.867 when 8-inch girder is made up of four 2-inch pieces.
.856 when 10-inch girder is made up of five 2-inch pieces.

NOTE.—Built-up girders of dressed lumber will carry somewhat smaller loads than solid girders, that is, two 2-inch dressed planks will equal only 3¼, whereas dressed 4-inch lumber will equal 3⅝. It is, therefore, necessary to multiply by the above figures in order to compute the loads for built-up girders.

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given on the right of these lines will cause a deflection in timbers of corresponding size and span, greater than 1/360 of the span. This is the limit usually set for deflection of girders and joists, lest plaster cracks, sticking doors, and other difficultines occur. Loads given to the left of this line will not cause serious deflection.

In most cases the lumber used for framing floors will be Southern yellow pine or Douglas fir. The zigzag lines apply for these two species only; and apply for all grades of these two species, even though the working stresses for lower grades are less than those given at the top of the tables. When other species of lower strength (working stress) are used, the larger sizes of timbers required to support these or lesser loads safely, will give, in practically all cases, a stiffer girder or joist.

NOTE: The joist and girder tables show that it will usually be found possible to use either of two timbers, one of which is 2 inches deeper than the other. For example, table 7-5 shows that either a 10 by 10 or an 8 by 12 will safely support a load of 10,000 over an 11-foot span. The deeper size will nearly always be preferable. In this example the 8 by 12 is both stronger and stiffer.

If, in the house discussed, a No. 1 common grade of Southern yellow pine is to be used, refer to table 7-5, based on a 1,200-pound fiber stress per square inch. Referring to the allowable girder loads, it is seen that from a span of 8 feet 5 inches a solid beam of dressed material 14 by 14 inches will carry 23,640 pounds, or more than the 22,750-pound load to be carried on this girder. Although this beam is larger than is customarily seen in small-house work, it is, nevertheless, required to carry properly the loads imposed.

The house plans referred to (see fig. 7-1) show on both sides of the girder a wide span approaching the usual maximum total of half widths. If wood girders were used, it would probably be advisable either to put in extra posts to reduce the girder span to about 5 feet, thus reducing the load to 13,500, for which a 10 by 14 inch of No. 1 common Southern pine would suffice, or to use a high grade dense structural timber, for which much higher stresses are allowable. Closer spacing of columns would materially reduce the load on columns and footings, and so improve the arrangement.

COLUMNS/POSTS

A bearing post or column is a vertical member designed to carry a superimposed vertical load. A foundation supports it either directly or indirectly. In light frame construction the post or column in the basement supports the girder. As pointed out in the previous section, the supporting post or column, in a house that is approximately square and large enough to require a girder, supported at the center, may carry one-fourth of the entire weight of the building. Therefore, the utmost care should be exercised in deciding upon the size, type, and material of the column, and in seeing that the column is properly seated on an adequate foundation.

The subject of spacing has been fully discussed in connection with girders and needs but brief mention here. Great distances between posts should be avoided for two reasons:

1. To avoid great concentration of weight on one footing.
2. To avoid the necessity of large girders required by long spans.

In general, it is wise to limit spans to between 8 and 10 feet. For spans over 12 feet in a 2-story house, the girders required must be deep; and, consequently, will reduce basement headroom, will be heavier and harder to handle, will naturally increase the cost, and will concentrate heavy loads on individual post footings. If in addition to long girder spans, the joist spans are also long, the disadvantages are even more noticeable.

Before the determination of size, it may be well to consider the manner in which a post acts. For this purpose, consider a 2-x 6-inch post about 2 feet long securely fastened in an upright position. One would have no hesitancy in bearing his whole weight upon it. Suppose, however, it were projected 20 feet above its support. With considerable hesitancy would any weight be put upon it. In fact, were it any thinner, there would be question as to whether it would stand up under its own weight. One is rigid because it is short, while the other bends because it is too long in proportion to its sectional area. Bending occurs most readily across the narrowest measurement. Tests show that the smaller dimension in any relatively long post is the principal governing factor in its capacity for support. Tests further show that if a wood column is more than fifty times as long as its least dimension, it is quite unsafe and its use should be avoided. Thus a dressed 2 by 6 inch or 2 by 4 inch, longer than about 6 or 7 feet, is unsafe as a post, unless braced sideways. For this reason, all strength tables for columns will show decreased bearing capacity with increase in length.

DETERMINING THE SIZE OF COLUMNS/POSTS

The first step in determining the size of a column is to find the load it must carry. As the post in the usual dwelling supports the girder, it must carry the weight brought to it by the girder. The girder, so far as the post is concerned, is a simple beam. In fact, the general rule, giving the proportion of the joist load carried by the girder, may be reworded slightly and used to show the proportion of the girder load supported by the posts.

GENERAL RULE: A post will carry the load on a girder to the midpoint of the span on both sides.

Computing Column/Post Loads

In computing post loads, the following procedure should be carried out:

1. Find the span in feet from the center of the post to the nearest girder support on one side.
2. Multiply this span in feet by the girder load per linear foot, using the method suggested in computing the girder size for this span.
3. Find the span in feet from the center of the post to the nearest girder support on the other side.
4. Multiply this span in feet by the girder load per linear foot as in No. 2.
5. Find the load on the post by consideration of which type of construction is used. For this purpose, consider the following CASES which represent the types of construction commonly encountered.

CASE 1.–Girder cut over the post in question and also over the two nearest supports. (See figure 7-10.) In this instance, post B takes one-half the total girder load on each side, so that the load on the post is one-half the girder weight itself and one-half the load carried by each length of girder.

CASE 2.–Girder continuous over the post in question but cut over the support on each nearest support. (See figure 7-11.) In this instance, post B carries approximately five-eighths of the load on the girder from A to C.

CASE 3.–Figure 7-12 gives a case of a continuous girder with two equidistant intermediate supports. It must be remembered that when more than one post is used, consideration must be given to each post separately. Although not exactly correct in all cases, the following rules are near enough for all practical purposes in considering this type of construction. Post B can be assumed to take five-eighths of the girder load from A to B and one-half the girder load

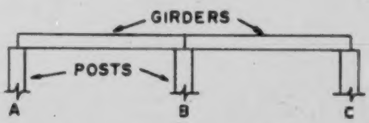

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Figure 7-10. —Case 1: Girder cut over center support and over supports on each side.

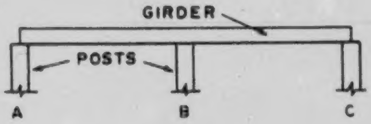

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Figure 7-11. —Case 2: Girder continuous over post but cut over supports on each side.

from B to C. In a similar manner post C may be considered to take five-eighths of the girder load from C to D and one-half of the girder load from C to B.

CASE 4.–In figure 7-13 a single girder is supported at five points, the three center posts equidistant and dividing the girder into four equal parts. As mentioned earlier, each post must be considered separately and a note made as to whether the girder is cut or continous over the post in question. In addition, consideration must also be made as to whether the girder is cut or continous over the nearest supports on both sides of the post in question.

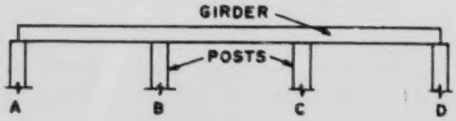

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Figure 7-12. –Case 3: Girder continuous over posts B and C but cut over the end supports.

Post C may be said to carry one-half of the load between C and B and C and D. Post B may be considered as carrying one-half the load between B and C and five-eighths of the load between B and A. In a similar manner post D may be said to carry one-half the girder load between D and C and five-eighths of the girder load between D and E.

Having determined the load on each post, the next step is to find the size required. This will depend on the material and type of post selected.

Selecting Column/Post Size

Other things being equal, round steel-pipe posts or square timber posts are preferred over other shapes, because they give equal strength in two directions and provide greater strength for the same area than any other cross sectional area. In order to determine the size of timber post required, refer to tables 7-7 and 7-8. To determine the size of steel-pipe post required,

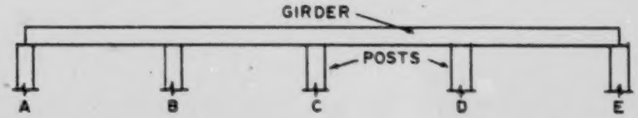

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Figure 7-13. –Case 4: Girder continuous over posts B, C, and D, but cut over the outer supports.

Table 7-7. –Maximum Load Allowance in Pounds for Lumber Columns of Douglas Fir, Southern Pine, and North Carolina Pine, No. 1 Common Grade

Nominal size, inches Actual size, inches Area in square inches	3 by 4 2⅝ by 3⅝ 9.51	4 by 4 3⅝ by 3⅝ 13.14	4 by 6 3⅝ by 5⅝ 20.39	6 by 6 5½ by 5½ 30.25	6 by 8 5½ by 7½ 41.25	8 by 8 7½ by 7½ 56.25
Height of column:						
4 feet	8, 720	12, 920	19, 850	30, 250	41, 250	56, 250
5 feet	7, 430	12, 400	19, 200	30, 050	41, 000	56, 250
6 feet	5, 630	11, 600	17, 950	29, 500	40, 260	56, 250
6 feet 6 inches	4, 750	10, 880	16, 850	29, 300	39, 950	56, 000
7 feet	4, 130	10, 040	15, 550	29, 000	39, 600	55, 650
7 feet 6 inches		9, 300	14, 400	28, 800	39, 000	55, 300
8 feet		8, 350	12, 950	28, 150	38, 300	55, 000
9 feet		6, 500	10, 100	26, 850	36, 600	54, 340
10 feet				24, 670	33, 600	53, 400
11 feet				22, 280	30, 380	52, 100
12 feet				19, 630	26, 800	50, 400
13 feet				16, 920	23, 070	47, 850
14 feet				14, 360	19, 580	44, 700

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Table 7-8. —Maximum Load Allowance in Pounds for Lumber Columns of Eastern Hemlock, Western Red Cedar, White Fir, White Pines, and Spruces, No. 1 Common Grade

Nominal size, inches	3 by 4	4 by 4	4 by 6	6 by 6	6 by 8	8 by 8
Actual size, inches	2⅝ by 3⅝	3⅝ by 3⅝	3⅝ by 5⅝	5½ by 5½	5½ by 7½	7½ by 7½
Area in square inches	9.51	13.14	20.39	30.25	41.25	56.25
Height of column:						
4 feet	4, 950	7, 280	11, 300	16, 940	23, 100	31, 500
5 feet	4, 380	7, 100	11, 000	16, 900	23, 060	31, 500
6 feet	3, 460	6, 650	10, 300	16, 700	22, 850	31, 500
6 feet 6 inches	2, 960	6, 320	9, 800	16, 600	22, 700	31, 400
7 feet		5, 960	9, 270	16, 400	22, 400	31, 300
7 feet 6 inches		5, 630	8, 720	16, 200	22, 100	31, 100
8 feet		5, 160	7, 930	15, 950	21, 800	31, 000
9 feet		4, 060	6, 300	15, 350	20, 950	30, 640
10 feet				14, 400	19, 600	30, 240
11 feet				13, 350	18, 200	29, 650
12 feet				12, 200	16, 600	28, 800
13 feet				10, 500	14, 350	27, 700
14 feet				8, 950	12, 200	26, 300

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refer to table 7-9. From the column on the left side of the appropriate table, select the height or length required and follow the line across to get the size of post that will carry the assumed load. For example, determine the size column required for a house 17 feet wide with a load on the girder of 2,700 pounds per linear foot and one center post.

It will be recalled (CASE 1) that where the girder is cut over the center post the post will carry one-half of the total girder load. The total load on the post will consequently be—

$$\frac{\text{8 ft 5 in. by } 2{,}700\text{ lb}}{2} + \frac{\text{8 ft 5 in. by } 2{,}700\text{ lb}}{2} = 22{,}750$$

Referring to the column tables for wood and pipe columns, suitable for a height of 6 feet 6

Table 7-9. —Steel-Pipe Columns–Standard Pipe Safe Loads in Thousands of Pounds

Nominal size, inches	6	5	4½	4	3½	3	2½	2	1½
External diameter, inches	6. 625	5. 563	5. 000	4. 500	4. 000	3. 500	2. 875	2. 375	1. 900
Thickness, inches	. 280	. 258	. 247	. 237	. 226	. 216	. 203	. 154	. 145
Effective length:									
5 feet	72. 5	55. 9	48. 0	41. 2	34. 8	29. 0	21. 6	12. 2	7. 5
6 feet	72. 5	55. 9	48. 0	41. 2	34. 8	28. 6	19. 4	10. 6	6. 0
7 feet	72. 5	55. 9	48. 0	41. 2	34. 1	26. 3	17. 3	9. 0	5. 0
8 feet	72. 5	55. 9	48. 0	40. 1	31. 7	24. 0	15. 1	7. 4	4. 2
9 feet	72. 5	55. 9	46. 4	37. 6	29. 3	21. 7	12. 9	6. 6	3. 5
10 feet	72. 5	54. 2	43. 8	35. 1	26. 9	19. 4	11. 4	5. 8	2. 7
11 feet	72. 5	51. 5	41. 2	32. 6	24. 5	17. 1	10. 3	5. 0	
12 feet	70. 2	48. 7	38. 5	30. 0	22. 1	15. 2	9. 2	4. 1	
13 feet	67. 3	46. 0	35. 9	27. 5	19. 7	14. 0	8. 1	3. 3	
14 feet	64. 3	43. 2	33. 3	25. 0	18. 0	12. 9	7. 0		
Area in square inches	5. 58	4. 30	3. 69	3. 17	2. 68	2. 23	1. 70	1. 08	0. 80
Weight per pound per foot	18. 97	14. 62	12. 54	10. 79	9. 11	7. 58	5. 79	3. 65	2. 72

Allowable fiber stress per square inch, 13,000 pounds for lengths of 60 radii or under, reduced for length over 60 radii.

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inches, the following sizes and materials will be found adequate:

> No. 1 common Douglas fir (West Coast), 6 by 6 inches, dressed size, will carry 29,300 pounds.
>
> No. 2 common Eastern hemlock, 6 by 8 inches, dressed size, will carry 22,700 pounds.
>
> Steel-pipe columns, 7 feet long and 3 inches in diameter, will carry 26,300 pounds.

Any of the foregoing posts could be used for this building. As to which would be best would depend upon preference, availability, and cost.

In small light frame structures it will often be found that a timber column smaller than 4 by 6 inches or 5 by 5 inches is satisfactory. However, no post smaller than 4 by 6 inches, and preferably 6 by 6 inches should be used in the basement because of the possibility of damage from a severe blow.

JOISTS

Joists are those members which actually carry the floors and ceilings between supports. The principles governing size of joists are the same as for girders. The first consideration, of course, is that there shall be ample strength. Many times, however, a joist which is strong enough may still be limber enough to permit a noticeable bending or vibration from walking. This not only is annoying but may be sufficient to crack the brittle plaster of the ceiling below. Stiffness, therefore, must also be considered as a factor. In table 7-10 the joist sizes recommended are adequate to carry the loads, and are also designed to give sufficient stiffness to prevent vibration harmful to plaster. Table 7-11 gives joist sizes suitable for light frame structures in which there is no plaster or where jarring is not objectionable. In order to use the tables, you need only to know the anticipated live load, span, spacing required, whether or not the ceiling is to be plastered, and the unit fiber stress and modulus of elasticity for the species and grades of wood to be used.

Table 7-10. —Maximum Spans For Joists (Uniformly Loaded) With Plastered Ceilings Below: Fiber Stress, 1,200 Pounds Per Square Inch; Modulus of Elasticity, 1,600,000

Live load—pounds per square foot	Spacing	2 inches wide by depth of—					3 inches wide by depth of—				
		6	8	10	12	14	6	8	10	12	14
	12	12-9	16-9	21-1	24-0	--------	14-7	19-3	24-0	--------	--------
10	16	11-8	15-4	19-4	23-4	24-0	13-6	17-9	22-2	24-0	--------
	24	10-3	14-6	17-3	20-7	24-0	11-11	15-9	19-10	23-9	24-0
	12	11-6	15-3	19-2	23-0	24-0	13-3	17-6	21-9	24-0	--------
20	16	10-5	13-11	17-6	21-1	24-0	12-0	16-1	20-2	24-0	--------
	24	9-2	12-3	15-6	18-7	21-9	10-6	14-2	17-10	21-6	24-0
	12	10-8	14-0	17-9	21-4	24-9	12-4	16-4	20-5	24-5	--------
30	16	9-9	12-11	16-3	19-6	22-9	11-4	14-11	18-9	22-7	26-4
	24	8-6	11-4	14-4	17-3	20-2	10-0	13-2	16-8	19-11	23-4
	12	10-0	13-3	16-8	20-1	23-5	11-8	15-4	19-3	23-1	26-11
40	16	9-1	12-1	15-3	18-5	21-5	10-8	14-0	17-8	21-3	24-10
	24	7-10	10-4	13-1	15-9	18-5	9-4	12-4	15-7	18-9	22-1
	12	9-6	12-7	15-10	19-1	22-4	11-0	14-7	18-4	22-0	25-8
50	16	8-7	11-6	14-7	17-6	20-5	10-0	13-4	16-10	20-3	23-8
	24	7-3	9-6	12-1	14-7	17-0	8-10	11-9	14-10	17-10	20-10
	12	9-0	12-0	15-2	18-3	21-4	10-6	14-0	17-7	21-1	24-7
60	16	8-1	10-10	13-8	16-6	19-3	9-7	12-10	16-1	19-4	22-7
	24	6-8	8-11	11-3	13-7	15-11	8-5	11-3	14-1	17-0	20-0
	12	8-7	11-6	14-6	17-6	20-6	10-1	13-5	16-11	20-5	23-9
70	16	7-8	10-2	12-10	15-6	18-3	9-3	12-3	15-5	18-7	21-10
	24	6-5	8-5	10-7	12-9	15-0	8-0	10-7	13-4	16-1	18-10

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Table 7-11. —Maximum Spans For Joists (Uniformly Loaded) With No Plastered Ceilings Below: Fiber Stress, 1,200 Pounds Per Square Inch

Live load—pounds per square foot	Spacing	2 inches wide by depth of—					3 inches wide by depth of—				
		6	8	10	12	14	6	8	10	12	14
30	12	13- 5	17- 8	22- 2	24- 0	--------	16- 8	21-10	24- 0	--------	--------
	16	11- 9	15- 6	19- 5	23- 3	24- 0	14- 7	19- 3	24- 0	--------	--------
	24	9- 8	12-10	16- 2	19- 5	22- 6	12- 1	16- 0	20- 1	24- 0	--------
40	12	12- 0	15-11	19-11	23-11	--------	15- 0	19- 8	24- 0	--------	--------
	16	10- 6	13-11	17- 4	20-11	21- 0	13- 1	17- 4	21- 8	24- 0	--------
	24	8- 7	11- 5	14- 5	17- 5	20- 3	10-10	14- 4	18- 0	21- 8	24- 0
50	12	10-11	14- 5	18- 2	21-11	24- 0	13- 8	18- 0	22- 6	24- 0	--------
	16	9- 6	12- 7	15-10	19- 1	22- 3	11-11	15- 9	19- 9	23- 9	24- 0
	24	7-10	10- 4	13- 1	15- 9	18- 5	9- 9	13- 0	16- 5	19- 9	23- 0
60	12	10- 0	13- 4	16-10	20- 2	23- 6	12- 7	16- 8	20-11	24- 0	--------
	16	8- 9	11- 8	14- 8	17- 8	20- 7	11- 0	14- 6	18- 4	22- 0	24- 0
	24	7- 3	9- 6	12- 1	14- 7	17- 0	9- 0	12- 0	15- 2	18- 3	21- 4
70	12	9- 5	12- 5	15- 8	18-11	22- 0	11-10	15- 7	19- 7	23- 6	24- 0
	16	8- 1	10-10	13- 8	16- 6	19- 3	10- 4	13- 7	17- 1	20- 7	24- 0
	24	6- 8	8-11	11- 3	13- 7	15-11	8- 5	11- 3	14- 1	17- 1	19-11
80	12	8- 9	11- 8	14- 9	17- 9	20-10	11- 1	14- 9	18- 6	22- 3	24- 0
	16	7- 8	10- 2	12-10	15- 6	18- 3	9- 9	12-10	16- 3	19- 6	22- 9
	24	6- 5	8- 5	10- 7	12- 9	15- 0	8- 0	10- 7	13- 4	16- 1	18-10

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Example 1.—The live load in a certain house is 40 pounds per square foot. The joist span on both floors is 15 feet, spaced 16 inches on center. The ceiling is plastered below. If common structural Douglas fir (West Coast) is to be used, which has a fiber stress of 1,200 pounds to the square inch and a modulus of elasticity of 1,600,000 pounds to the square inch as determined from table 7-2, table 7-10 will apply for determining the size. By following to the right on the line of 40 pounds and using the 16-inch spacing, it will be found that 15 feet 3 inches is the maximum permissible span for a 2 by 10. Therefore, the correct size joist for both the first and second floors of this house will be common structural West Coast Douglas fir, 2 by 10 inches.

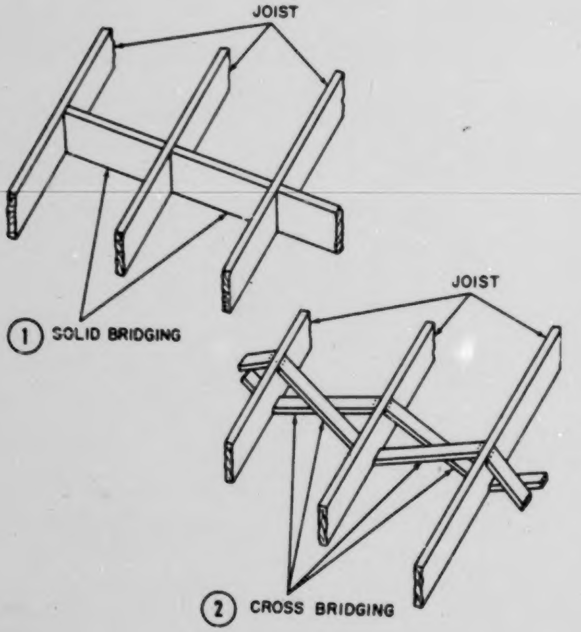
Example 2.—For the same house, to determine the size of the attic joists, using common structural Douglas fir (West Coast), table 7-10 can again be used. The live load will be 20 pounds. For 16-inch spacing, a 2 by 10 joist will be required, with a maximum span of 17 feet 6 inches for this size. A 2- by 8-inch joist would not be suitable for spans over 13 feet 11 inches, with the floor loadings assumed.

NOTE: The tables shown do not cover each and every species and grade of lumber that you may encounter; however, they do represent the more common species and grades. Should you need information relative to other species and grades, consult the appropriate references or publications maintained in the battalion technical library.

BRIDGING

When joists are used over a long span, they have a tendency to sway from side to side. Bridging is used in order to stiffen the floor frame, to prevent unequal deflection of the joists, and to enable an overloaded joist to receive some assistance from the joists on either side of it.

Bridging is of two types; horizontal or solid bridging (view 1, figure 7-14) and cross bridging (view 2, figure 7-14). Cross bridging is the one most generally used; it is very effective and requires less material than horizontal bridging. If the joists have a span of more than 10 feet, at least one row of bridging should be introduced to add stiffness to the floor. For spans greater than 14 or 16 feet, two rows of bridging are



45.440
Figure 7-14. —Types of bridging.

considered necessary, as they should not be farther apart than 7 or 8 feet.

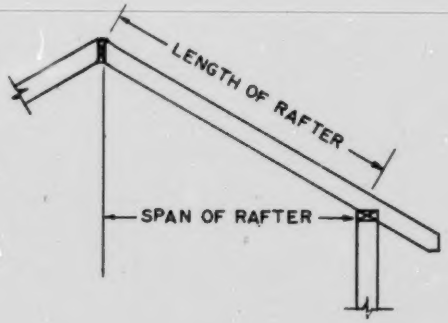
RAFTERS

Rafters serve the same purpose for the roof as do joists for floors in providing a support for sheathing and roofing material. The size of roof rafters will depend upon three factors:

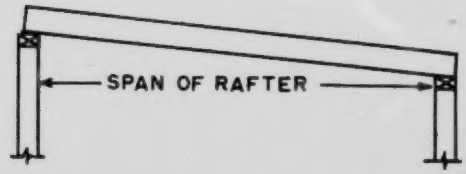
1. The span;
2. The weight of the roof material; and
3. The snow and wind loads.

Proper recommendations as to loads to be allowed for are made in figure 7-9. Knowing the span, the dead and live loads, and the type of material to be used, rafter size can be determined using the appropriate joist table.

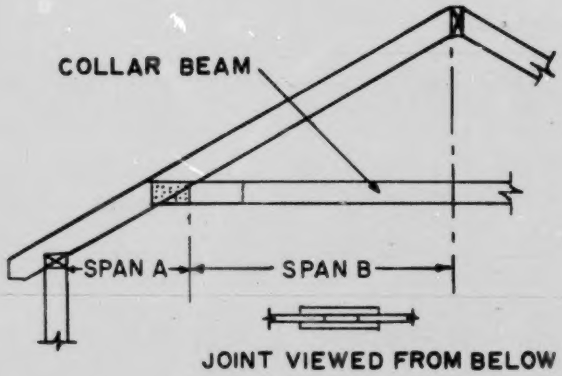
As there is likely to be some misconception as to what is meant by the span of a roof rafter, especially if its slope is considerable, the following definition is given. The "rafter span" is the horizontal distance between the supports and not the length along the rafter. The span may be between wall-plate and ridge (figure 7-15), or from wall to wall (figure 7-16), or from wall to collar beam connection, or from collar beam to ridge, whichever is greatest (figure 7-17).



117.397
Figure 7-15. —Rafter span between wallplate and ridge.



117.398
Figure 7-16. —Span of rafter when measured from wall to wall.



117.399
Figure 7-17. —Determining span when a collar beam is used on every rafter. The span is B because it is the larger of the two spans.

HEADERS

Headers encountered in light frame construction are of two classes: nonbearing and load-bearing. Nonbearing headers occur in walls which are parallel with the joists of the floor above and carry only the weight of the framing immediately above. Load-bearing headers occur in walls which carry the ends of the floors immediately above the opening, in floors at openings in the joists for stairs, and in roofs at openings in the rafters for dormers.

NONBEARING HEADERS

Unless the opening in a nonbearing partition is more than 3 feet wide, a single 2 by 4 is satisfactory as a header. This size is sufficiently strong and eliminates the likelihood of plaster cracks due to expansion or shrinkage. It often happens, however, that trim inside and outside is so wide as to prevent satisfactory nailing over openings with a single 2 by 4. In such cases it will become necessary to double the header merely to provide a nailing base for trim–not for structural strength.

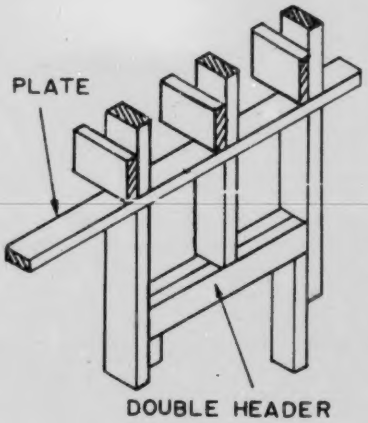
LOAD-BEARING HEADERS

As mentioned earlier, there are two types of load-bearing headers encountered in light frame construction, those being the one occurring in load-bearing partitions or walls and those occurring in floor openings.

Wall Openings

On load-bearing partitions or walls the header should be doubled, even over narrow openings, especially if a short stud occurs near the center of the header. (See figure 7-18.) The header should rest on the studs as shown.

If the 2 by 4's placed over the opening are placed one above the other, they should be thoroughly spiked together in order to support the load. If the 2 by 4's used as a header, instead of being laid horizontally are placed vertically side by side, the spiking will not be quite as important, since each piece will offer greater resistance to bending than when laid flat. It must be noted, however, that the two 2 by 4's laid on edge will together measure only 3 1/4 inches instead of 3 5/8 inches when laid flat. Consequently, it will be necessary to insert small pieces of lath between the 2 by 4's in order to make the header line up with the studs.



117.400

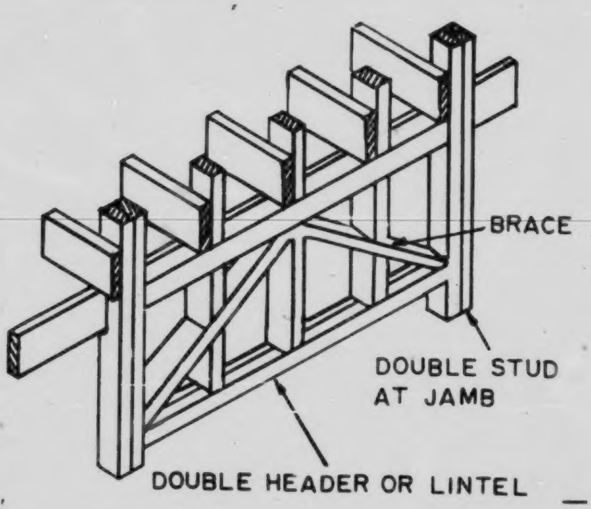
Figure 7-18. –Double header.

If the opening is more than 3 feet in width, the header will need additional strength to carry the weight imposed upon it from above. This additional strength may be secured by using material of greater cross section than 2 by 4's. For openings ranging from 3 to 6 feet, 2 by 4's should be used to form a truss. A truss over an opening in light frame construction is in general a triangular arrangement of 2 by 4's forming a rigid framework for the support of weight above. (See figure 7-19.) Theoretically the only stresses placed on a truss are compression and tension.

For distances over 6 feet, or where unusually heavy weights must be supported, it is advisable to use a girder. The discussion and tables on girders and columns can be used to determine sizes and materials.

Floor Openings

Whenever it is necessary to cut regular joists to provide an opening as, for example, at the stair well, it is necessary to provide auxiliary



117.401
Figure 7-19. —Trussing arrangement.

joists (headers) at right angles to the regular joists, to carry the ends of the cut joists which are called tail beams. These headers, in turn, are supported by double or triple joists called trimmers. Whatever its strength requirements, a header cannot be of greater depth than the joists, except perhaps on the first floor where projection below the ceiling line of the basement is not objectionable. Custom has usually decreed the doubling of all headers and trimmers. As a matter of fact, size should be determined on the basis of loads to be carried. In many cases it is unnecessary to double the members. On the other hand, there are cases in which doubling of headers may be insufficient.

The header is similar to a girder in that it carries the end of certain floor joists. Before the load on the trimmer can be found, it is necessary to find the load carried by the header. This load may be found by following the same methods as outlined for girders. As a matter of convenience, however, the general rule for girders may be modified for the header as follows:

GENERAL RULE FOR HEADERS: The header will carry the weight of the floor to the midpoint of the tail beams which rest upon it.

Therefore, the load on the header is: Length of tail beam multiplied by length of header multiplied by floor load (both live and dead) in pounds per square foot divided by 2. An illustration of a case may be taken where a tail beam is 12 feet long, the length of the header 6 feet, and the floor load 50 pounds to the square foot. The figures for this example are as follows:

$$\frac{12 \times 6 \times 50}{2} = 1{,}800 \text{ pounds}$$

It was seen in the simple case of the joist resting on supports at either end that the load on the joist is divided equally between the supports. In like manner, the two trimmers will divide the total header load. Summarizing the foregoing: The header takes half the floor load on the tail beams and the trimmers each take half of the header load, so the trimmer carries one-fourth of the floor load carried by the tail beams. The following rule may therefore be formulated:

GENERAL RULE FOR TRIMMER LOADS: Trimmer load = one-fourth (length of header by length of tail beams by their total floor load, live plus dead in pounds per square foot).

The figures in table 7-12 are arranged according to total floor load (live plus dead) and length of tail beams. These figures multiplied by the length of the header will give the total uniformly distributed load on the header. Half this amount gives the concentrated load on each trimmer corresponding to the foregoing formula.

The next step in determining the trimmer is to note the point of application of the header load and to ascertain its effect upon the trimmer. Nearly all tables for beams are based on uniformly distributed loads. It will be recalled that a concentrated load of 1,000 pounds applies at the center of a span produces the same effect as a uniformly distributed one of twice the amount, or 2,000 pounds. Simple reference to the girder tables will give the proper size of beams required for any such concentrated load, for any span or material, merely by doubling it and treating as a uniformly distributed load. If the relation can be found between the bending effect of a concentrated load at points other than the center, and a corresponding uniformly

Table 7-12. —Table For Use in Figuring Header and Trimmer Loads

Length of tail beams	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Total live and dead loads per square foot:																	
10	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300
40	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
50	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500
60	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540	570	600
70	140	175	210	245	280	315	350	385	420	455	490	525	560	595	630	665	700
80	160	200	240	280	320	360	400	440	480	520	560	600	640	680	720	760	800
90	180	225	270	315	360	405	450	495	540	585	630	675	720	765	810	855	900
100	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1,000

117.402

distributed load of equal bending effect, the size of beam may be quickly found from the tables by using the equivalent uniformly distributed load. This relationship has been established and is shown in table 7-13. The concentrated load multiplied by the proper factor (determined by position of load) from table 7-13 gives the uniform load which can be used to select from the tables of maximum spans the necessary size of joist or trimmer to be used. The best way to summarize the discussion dealing with load-bearing and trimmers around floor openings is to work an example.

EXAMPLE.—Assume a hearth 6 feet long in a living room 14 feet wide; the header is to be 2 feet from one end of the trimmer (see figure 7-20); assume the usual live load of 40 pounds and a dead-load allowance for the weight of the floor of 10 pounds with no plaster below. The tail beams, therefore, are 12 feet long.

1. According to the tables, the joists, if of No. 1 common Southern pine, would be 2 by 10's; hence, the header and trimmer depth would be limited to 10 inches.

2. The load on the header, according to table 7-12, would be 300 by 6, or 1,800 pounds. Girder tables show that a 2 by 10 of 6-foot span, for example, will carry 2,020 pounds; therefore, it is not necessary to double the header.

3. Load on trimmer is one-half header load, or 900 pounds.

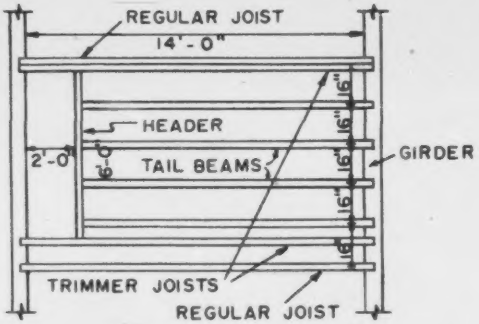
4. The trimmer load is applied 2 feet from one end of the trimmer, so it is one-seventh of the span from one end. According to table 7-13, this is equivalent in bending effect to an equal load of 900 pounds distributed over the whole beam.

Table 7-13. —Relationship Between Bending Effect of Concentrated and Uniformly Distributed Loads

Load	Position of load	Factor
Concentrated	Applied at center of span	Multiply by 2.
Do	Applied at one-third of span	Multiply by 1¾.[1]
Do	Applied at one-fourth of span	Multiply by 1½.
Do	Applied at one-fifth of span	Multiply by 1¼.[1]
Do	Applied at one-seventh of span	Multiply by 1.
Do	Applied at one-eighth of span	Multiply by ⅞.
Do	Applied at one-tenth of span	Multiply by ¾.[1]

[1] These factors are to the nearest simple fraction, but are close enough for practical purposes and are based on a similar table by Kidder-Nolan.

117.403



117.404

Figure 7-20. —Hearth opening requiring calculations to determine header and trimmer sizes.

5. Girder tables show that a 2 by 10 of common structural Douglas fir with a 14-foot span will carry 1,336 pounds. This is ample to carry the header.

6. If the regular joist is used as a trimmer also, it must support the header load in addition to its share of the floor load, which it is seldom able to do.

In such instances the joist must carry a strip of floor 16 inches wide with a combined live and dead load of 50 pounds. The total loads on the joist in the example above, therefore, would be: Joist load equals 14 feet (length) by 1-1/3 feet (spacing) by 50 pounds load per square foot, or 932 pounds, plus the header load in terms of its equivalent, uniformly distributed load, or 900 pounds. The trimmer joist to carry both loads must have a capacity of 1,832 pounds, but reference to girder tables show that a 2 by 10 of Douglas fir has a capacity of only 1,336 pounds as determined earlier. Therefore, if a single piece is to act as both joist and trimmer, its size will have to be increased to 3 by 10, which for a 1,200 pound fiber stress will carry 2,152 pounds.

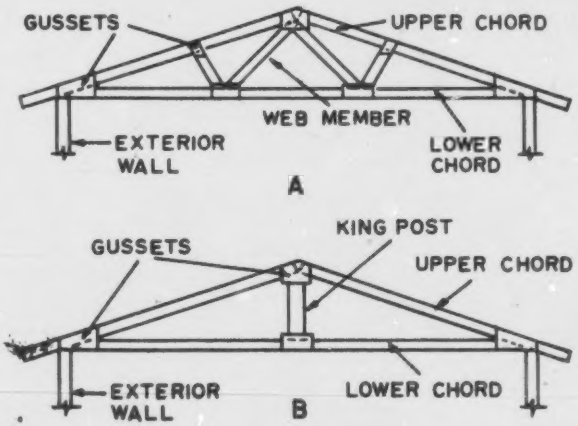
Roof Openings

Just as there are headers and trimmers for floor openings, so there are corresponding headers and trimmers for roof openings. The method of determining their size is the same as that outlined for joist headers and trimmers; therefore, no further discussion is necessary.

WOOD TRUSSES

A wood truss is an assembly of members forming a rigid framework of triangular shapes capable of supporting loads over long spans without intermediate support. Its members are connected only at their intersections in such a way that if loads are applied at these intersections the stress in each member is in the direction of its length. The wood truss has been greatly refined during its development over the years, and the gusset and other preassembled types of wood trusses are being used extensively in light frame construction.

The common W-type truss (view A, figure 7-21) for moderate spans requires less material than the conventional joist and rafter framing system, as the members are usually only 2 by 4 inches in size for spans of 24 to 32 feet. The king-post truss (view B, figure 7-21) for spans of 20 to 26 feet uses even less material than the W-truss, but is perhaps more suitable for light to moderate roof loads. In addition to lowering material costs, the truss has the advantage of permitting freedom in location of interior partitions because only the sidewalls carry the ceiling and roof loads. The principal parts of a truss are the upper chord (consisting of rafters), the lower



117.405

Figure 7-21. —Trussed rafters.

chord (corresponding to a ceiling joist), various diagonal and/or vertical bracing members which are known collectively as the web members, and the connecting members called gussets.

The roof sheathing, trim, roofing, interior ceiling finish, and type of ceiling insulation used do not vary a great deal between the truss and conventional roof systems. For plywood or lumber sheathing, 24-inch spacing for truss and joist-rafter construction is considered a normal maximum. Greater spacing can be used, but it usually requires a thicker roof sheathing and application of wood stripping on the underside of the ceiling joists and trusses to furnish a support for ceiling finish. Thus, most W-trusses are designed for 24-inch spacing and joist-rafter construction for 24- or 16-inch spacing. Trusses generally require a higher grade of material than the joist and rafter roof. However, specific details of the roof construction are covered in the working drawings for each structure. Additional information concerning the design and construction details for other types of wood trusses is available from several sources including The American Plywood Association.

DESIGN AND FABRICATION

The design of a truss not only includes snow and windload considerations but the weight of the roof itself. Design also takes into account the slope of the roof. Generally, the flatter the slope, the greater the stresses. This results not only in the need for larger members but also in stronger connections. Consequently, all conditions must be considered before the type of truss is selected and designed.

A great majority of the trusses used are fabricated in a central shop. While some are constructed at the jobsite, an enclosed building provides better control for their assembly. The three most common methods of fastening members together are with metal truss plates, plywood gussets, and ring connectors. The metal truss plates, with or without prongs, are fastened in place on each side of member intersections. Some plates are nailed and others have supplemental nail fasteners. Trusses using metal truss plates are best assembled in a small central shop as they are not easily adapted to on-site fabrication.

The plywood-gusset type truss may be a nailed or nailed-glued combination. The nailed-glued combination, with nails supplying the pressure, allows the use of smaller gussets than does the nailed system. However, if on-site fabrication is necessary, the nailed gusset truss and the ring connector truss are probably the best choices as many adhesives suitable for trusses generally require temperature control and weather protection not usually available on site. The size of the gussets, the number of nails or other connectors, and other details for this type of roof are included in the working drawings, an example of which is shown in figure 7-22.

Handling

In handling and storage of completed trusses, avoid placing unusual stresses on them. They were designed to carry roof loads in a vertical position, and it is important that they be lifted and stored in an upright position. If they must be handled in a flat position, enough men or supports should be used along their length to minimize bending deflections. Never support them only at the center or only at each end when in a flat position.

Erection

Completed trusses can be raised in place with a small mechanical lift on the top plates of exterior sidewalls. They can also be placed by hand over the exterior walls in an inverted position, and then rotated into an upright position by means of a pole or rope. The top plates of the two sidewalls should be marked for the location of each set of trusses. Trusses are fastened to the outside walls and to 1 by 4 or 1 by 6 temporary horizontal braces used to space and align them until the roof sheathing has been applied. Trusses can be fastened to the top wallplates by toenailing, but this is not always the most satisfactory method. The heel gusset in a plywood gusset truss is located at the wallplate and makes toenailing difficult. However, two tenpenny nails at each side of the truss can be

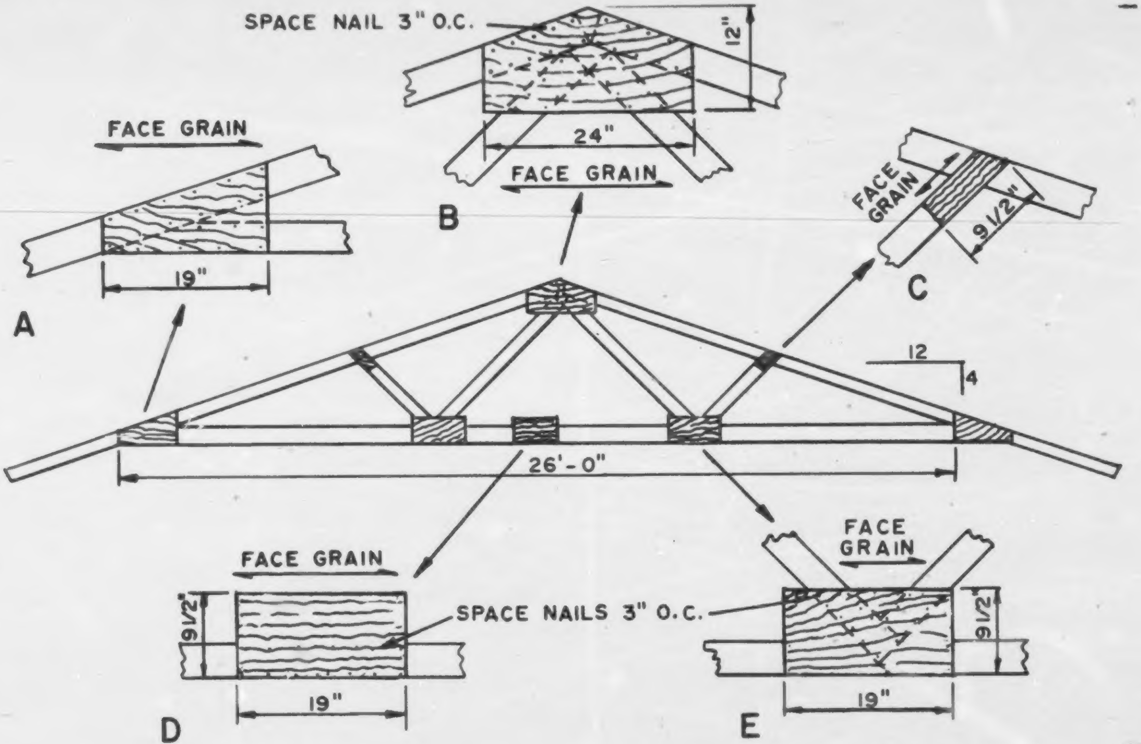


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Figure 7-22. —Construction of a 26-foot W truss: (A) Bevel-heel gusset; (B) Peak gusset; (C) Upper chord intermediate gusset; (D) Splice of lower chord; (E) Lower chord intermediate gusset.

used in nailing the lower chord to the plate (view A, figure 7-23). Predrilling may be necessary to prevent splitting. A better system involves the use of a simple metal connector or plate anchor (available commercially or can be formed from sheet metal), shown in view B of figure 7-23. Plate anchors should be nailed to the wallplates at sides and top with eightpenny nails and to the lower chords of the truss with sixpenny or 1-1/2-inch roofing nails.

RIGID FRAME BUILDINGS

One of the most widely used types of buildings at overseas bases is the rigid frame utility building. These are preengineered (usually called prefabricated) structures consisting of a metal framework covered with sheet metal. Rigid frame buildings are ideally suited for use as repair shops or warehouses since they have large, clear-span floor areas—without columns or other obstructions—and straight sidewalls which, in turn, permit floor-to-ceiling storage of products and wall-to-wall placement of machinery. The rigid frame buildings currently used by the SEABEES are manufactured by the Butler and Pascoe manufacturing companies. The buildings are shipped in compact crates (labeled as to contents) and come complete with assembly tools and instructions. Insofar as there is no great difference between the two, the discussion here will be devoted to those manufactured by the Butler Manufacturing Company.

The basic Butler building which is 40′ wide by 100′ long can be readily adapted to varying lengths and purposes by subtracting or adding

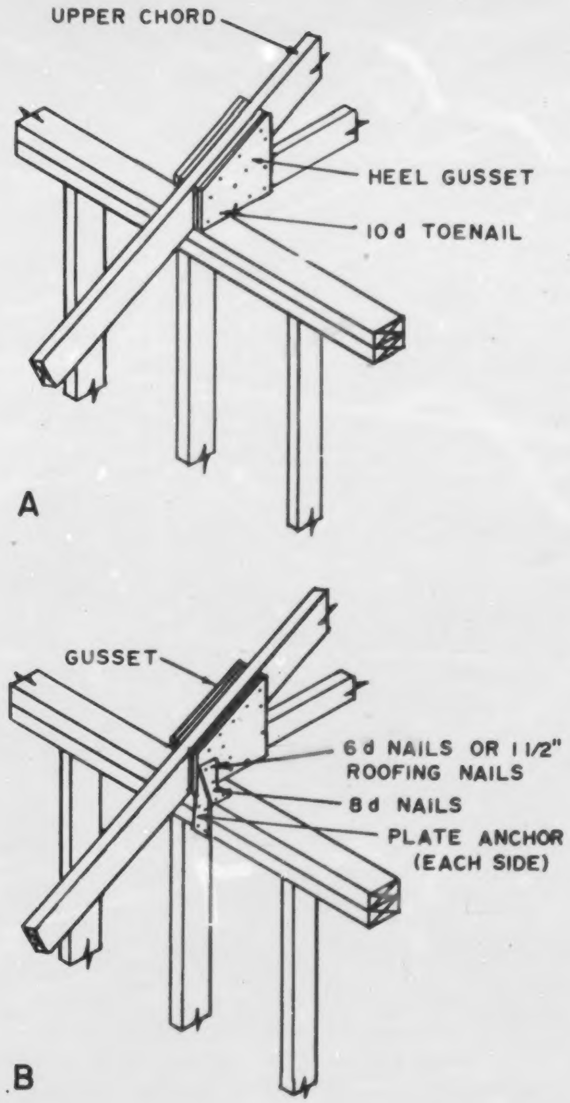


Figure 7-23. —Fastening trusses to wallplate.

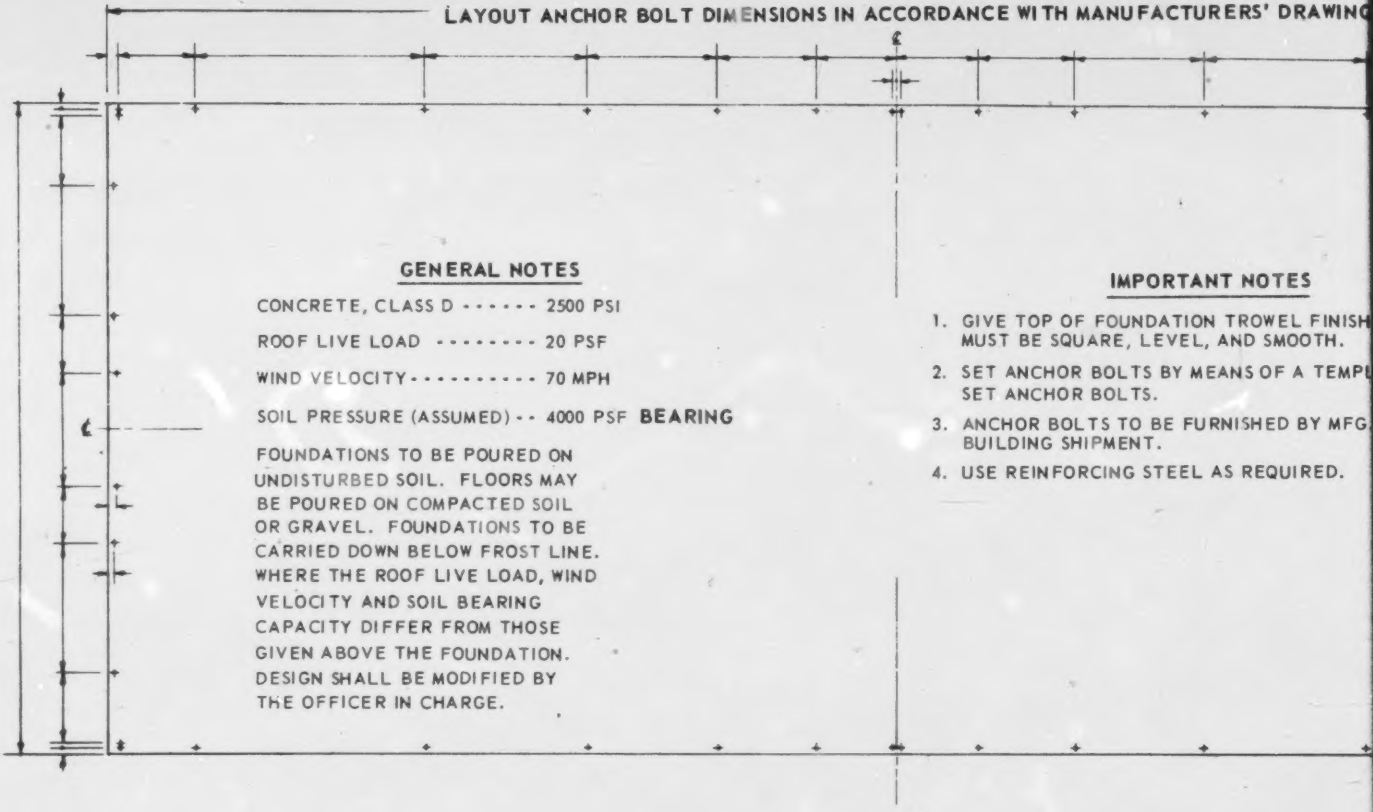
bays and making the necessary foundation adjustments. In addition to the basic Butler building, other types of prefabricated buildings (usually smaller in floor area) are also used at SEABEE activities. One such building is the 20′ by 48′ Butlerhut. If you recall the discussion of rigid frame buildings in the *Builder 3 & 2* Rate Training Manual, you will remember that the assembly and erection procedures for the Butlerhut were given in detail with no mention of the basic Butler building. The reason for this is that Builders are responsible for the assembly and erection of the Butlerhut while the assembly and erection of the basic Butler building is the responsibility of the Steelworkers. Regardless of who is responsible for the assembly and erection of the different buildings, the responsibility for laying out foundations and slabs for steel rigid frame buildings rests with the Builder.

Quite a lot of preliminary work is necessary before actual erection of a rigid frame building can begin. After the building site is selected, Engineering Aids are responsible for establishing grade elevation and corner point locations as well as for determining the soil bearing capacity. Once the foundation is outlined, Equipment Operators are responsible for general site preparation to include the grading and excavating required before actual construction operations can begin. Builders will make the forms for the concrete work and pour the concrete. As you can see, the preparation for and the assembly and erection of rigid frame buildings could involve personnel from nearly all the Group VIII ratings. This being the case, it is essential that jobs of this type be preplanned so as to coordinate the activities of each of the ratings involved.

FOUNDATION AND FLOOR SLAB LAYOUT

The typical foundation and floor slab layout requirements for a 20′ by 48′ rigid frame building are shown in figure 7-24. Note the different slab assemblies based on anticipated floor loads and that the material requirements are given for each type assembly. Note also that the buildings may be erected in multiples. The arrangements indicated show the buildings erected end-to-end. They may also be erected side-by-side. Figure 7-25 shows two Pascoe buildings being erected side-by-side in a Homeport Project by NMCB 71. Note that in the foundation system used in this project, piers were constructed in order to increase overhead clearance of the standard structure. As you can see, modifications can be made not only to

LAYOUT ANCHOR BOLT DIMENSIONS IN ACCORDANCE WITH MANUFACTURERS' DRAWIN



GENERAL NOTES

CONCRETE, CLASS D - - - - - - 2500 PSI

ROOF LIVE LOAD - - - - - - - - 20 PSF

WIND VELOCITY - - - - - - - - - - 70 MPH

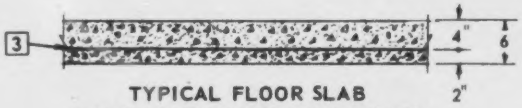
SOIL PRESSURE (ASSUMED) - - 4000 PSF BEARING

FOUNDATIONS TO BE POURED ON UNDISTURBED SOIL. FLOORS MAY BE POURED ON COMPACTED SOIL OR GRAVEL. FOUNDATIONS TO BE CARRIED DOWN BELOW FROST LINE. WHERE THE ROOF LIVE LOAD, WIND VELOCITY AND SOIL BEARING CAPACITY DIFFER FROM THOSE GIVEN ABOVE THE FOUNDATION. DESIGN SHALL BE MODIFIED BY THE OFFICER IN CHARGE.

IMPORTANT NOTES

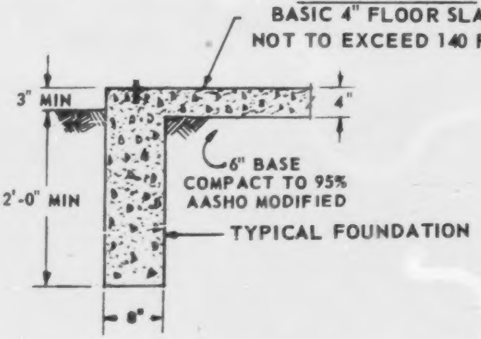
1. GIVE TOP OF FOUNDATION TROWEL FINISH MUST BE SQUARE, LEVEL, AND SMOOTH.
2. SET ANCHOR BOLTS BY MEANS OF A TEMP SET ANCHOR BOLTS.
3. ANCHOR BOLTS TO BE FURNISHED BY MFG BUILDING SHIPMENT.
4. USE REINFORCING STEEL AS REQUIRED.

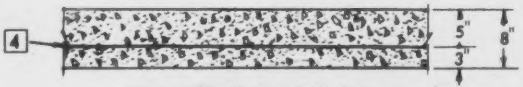
ANCHOR BOLT LAYOUT
BUILDING ON CONCRETE SLAB
SCALE: $\frac{3}{8}$" = 1' -0"



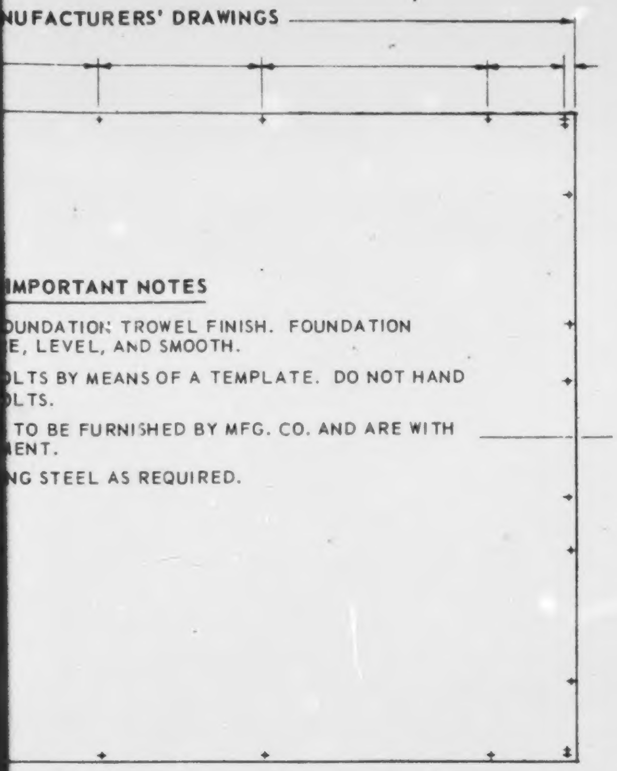
TYPICAL FLOOR SLAB
UNDER LIGHT WEIGHT MACHINES
NOT TO EXCEED 200 PSF
ASSEMBLY 1416

ASSEMBLY 1415
BASIC 4" FLOOR SLAB
NOT TO EXCEED 140 PSF





TYPICAL FLOOR SLAB
UNDER MEDIUM WEIGHT MACHINES
NOT TO EXCEED 300 PSF
ASSEMBLY 1417


NUFACTURERS' DRAWINGS

IMPORTANT NOTES

OUNDATION TROWEL FINISH. FOUNDATION
E, LEVEL, AND SMOOTH.

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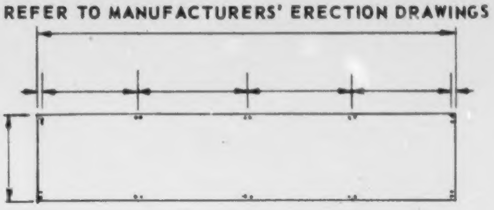
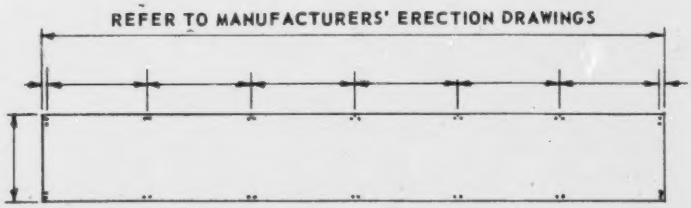
OLTS.

TO BE FURNISHED BY MFG. CO. AND ARE WITH
MENT.

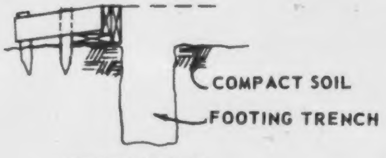
NG STEEL AS REQUIRED.


REFER TO MANUFACTURERS' ERECTION DRAWINGS

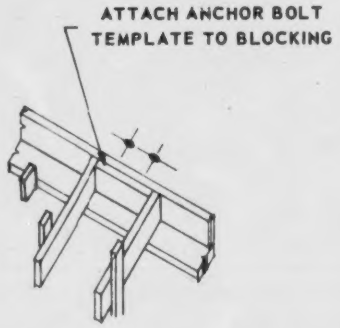
TWO BUILDINGS IN MULTIPLE

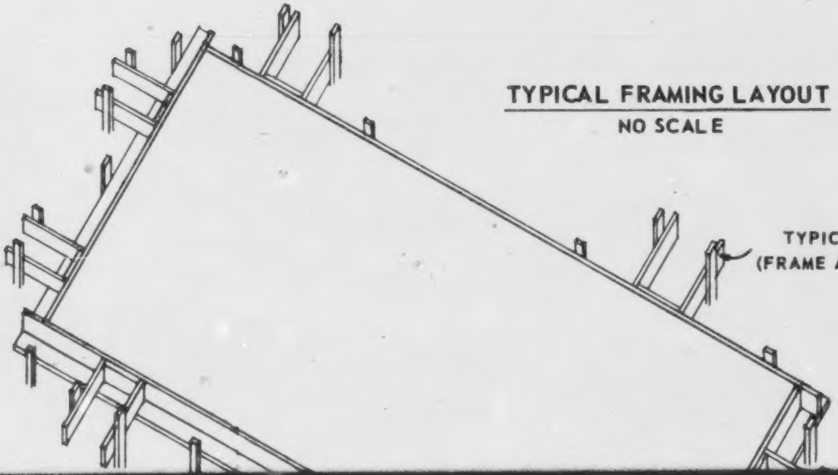

REFER TO MANUFACTURERS' ERECTION DRAWINGS

THREE BUILDINGS IN MULTIPLE

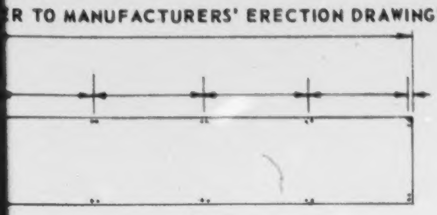

COMPACT SOIL
FOOTING TRENCH

SECTION A-A

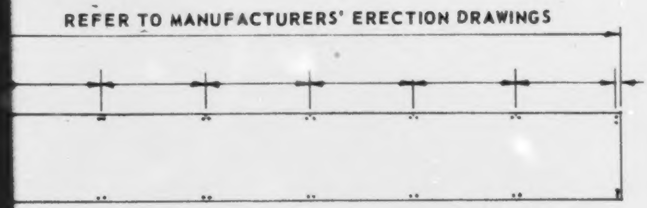

ATTACH ANCHOR BOLT TEMPLATE TO BLOCKING


TYPICAL BRACE, (FRAME AS REQUIRED)

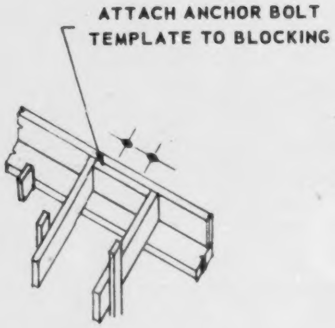
TYPICAL FRAMING LAYOUT
NO SCALE


R TO MANUFACTURERS' ERECTION DRAWINGS

TWO BUILDINGS IN MULTIPLE

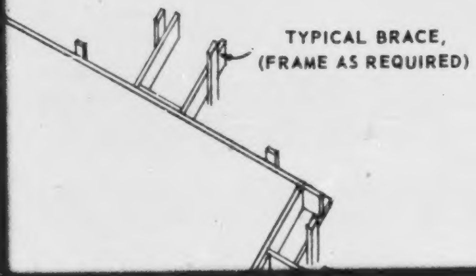

REFER TO MANUFACTURERS' ERECTION DRAWINGS

THREE BUILDINGS IN MULTIPLE


ATTACH ANCHOR BOLT TEMPLATE TO BLOCKING

TYPICAL FRAMING LAYOUT

NO SCALE

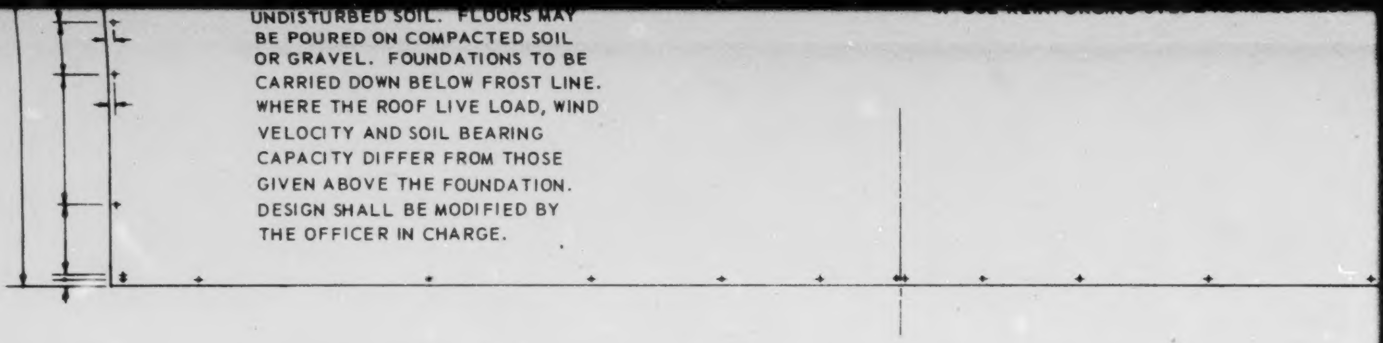

TYPICAL BRACE,
(FRAME AS REQUIRED)

BILL OF MATERIAL

ITEM	DESCRIPTION	UNIT	ASSEMBLY	QUAN.	ZONE
	MATERIAL FOR FOUNDATION AND FLOOR SLAB FOR 20 X 48 RIGID FRAME BUILDING (4" SLAB)				
	4 INCH SLAB AND FND.		1415		
1	LUMBER, 2 X 4 S4S (FORMS)	BF		350	
2	NAIL, DOUBLE HD. GALV. 8D	LB		3	
3	CEMENT, 1-A EXPORT	BG		140	
4	NAIL COMMON BRITE 12D	LB		5	
	NOTE: THE ABOVE ASSEMBLY (1415) IS A STANDARD 4" SLAB AND FOUNDATION FOR A 20 X 48 BLDG, THE FOLLOWING ASSEMBLIES SHOULD BE FURNISHED IN-LIEU OF 1415 WHEN HEAVY-DUTY SLABS ARE REQUIRED:				
	6 INCH SLAB AND FND.		1416		
1	LUMBER, 2 X 6 S4S (FORMS)	BF		450	
2	NAIL, DOUBLE HD. GALV. 8D	LB		4	
3	WIRE, FABRIC REINF. 6 X 6 X NO. 6	RL		2	
4	CEMENT, 1-A EXPORT	BG		190	
5	NAIL COMMON BRITE 12D	LB		5	
	8 INCH SLAB AND FND.		1417		
1	LUMBER, 2 X 8 S4S (FORMS)	BF		200	
2	LUMBER, 2 X 6 S4S (FORMS)	BF		350	
3	NAIL, DOUBLE HD. GALV. 8D	LB		5	
4	WIRE, FABRIC REINF. 6 X 6 X NO. 6	RL		2	
5	CEMENT, 1-A EXPORT	BG		225	
6	NAIL COMMON BRITE 12D	LB		5	
	12 INCH SLAB AND FND.		1418		
1	LUMBER, 2 X 6 S4S (FORMS)	BF		1200	
2	NAIL, DOUBLE HD. GALV. 8D	LB		7	
3	WIRE, FABRIC REINF. 6 X 6 X NO. 6	RL		4	
4	CEMENT, 1-A EXPORT	BG		300	
5	NAIL COMMON BRITE 12D	LB		5	

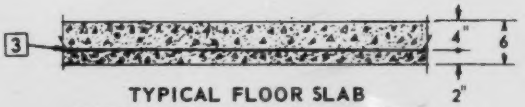
NOTES:

1. SUGGESTED LAYOUT SUBJECT TO APPROVAL OF BASE COMMANDER
2. SEE LATEST EDITION NAVFAC P-103 FOR STOCK NUMBERS AND SHIPPING QUANTITIES.



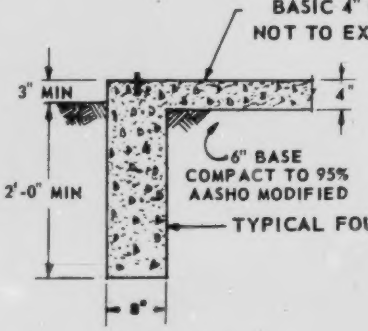
UNDISTURBED SOIL. FLOORS MAY BE POURED ON COMPACTED SOIL OR GRAVEL. FOUNDATIONS TO BE CARRIED DOWN BELOW FROST LINE. WHERE THE ROOF LIVE LOAD, WIND VELOCITY AND SOIL BEARING CAPACITY DIFFER FROM THOSE GIVEN ABOVE THE FOUNDATION. DESIGN SHALL BE MODIFIED BY THE OFFICER IN CHARGE.

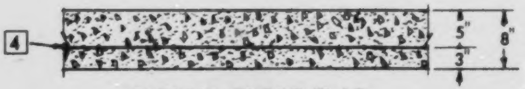
ANCHOR BOLT LAYOUT
BUILDING ON CONCRETE SLAB
SCALE: 3/8" = 1' -0"



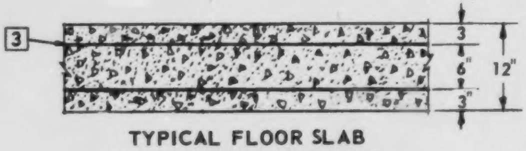
TYPICAL FLOOR SLAB
UNDER LIGHT WEIGHT MACHINES
NOT TO EXCEED 200 PSF
ASSEMBLY 1416

ASSEMBLY 1415
BASIC 4" FLOOR SLAB
NOT TO EXCEED 140 PSF


3" MIN
4"
6" BASE
COMPACT TO 95%
AASHO MODIFIED
2'-0" MIN
TYPICAL FOUNDATION
8"



TYPICAL FLOOR SLAB
UNDER MEDIUM WEIGHT MACHINES
NOT TO EXCEED 300 PSF
ASSEMBLY 1417



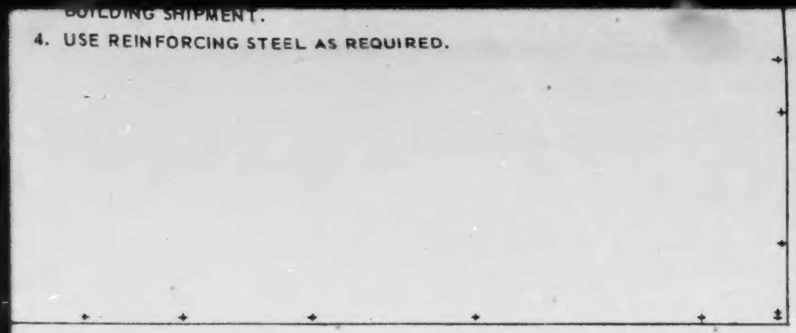
TYPICAL FLOOR SLAB
UNDER HEAVY MACHINES
NOT TO EXCEED 660 PSF
ASSEMBLY 1418

TYPICAL DETAILS OF
4"–6"–8"–12" SLAB
SCALE: 1" = 1' - 0"

Figure 7-24. —Fo

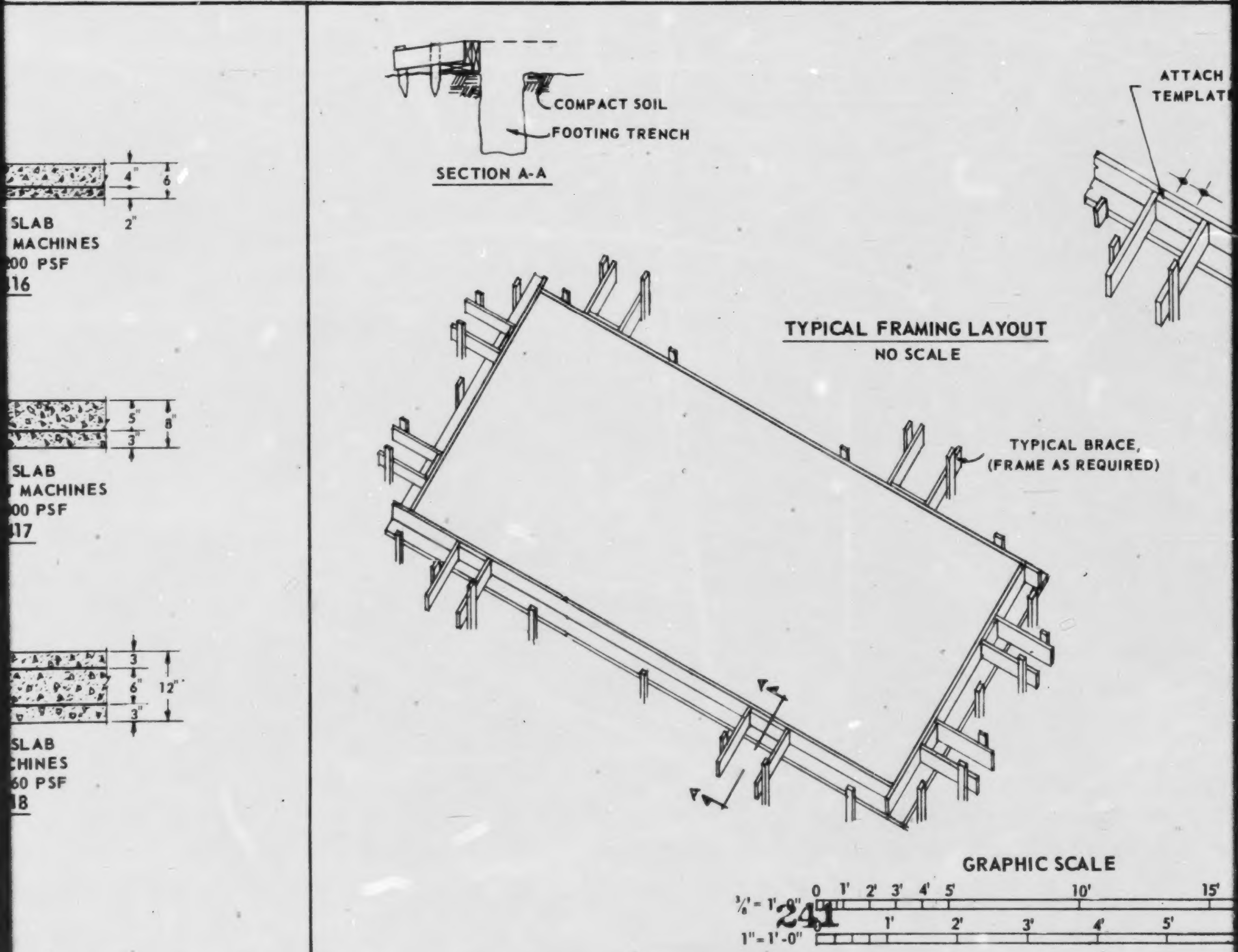
BUILDING SHIPMENT.

4. USE REINFORCING STEEL AS REQUIRED.



THREE BUILDINGS IN MULTIPLE

BOLT LAYOUT
CONCRETE SLAB
3/8" = 1' -0"

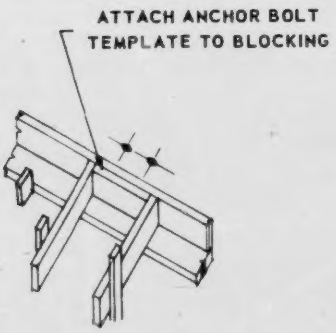


4"
6
2"
SLAB
MACHINES
200 PSF
316
5"
8"
3"
SLAB
T MACHINES
00 PSF
317
3
6"
12"
3"
SLAB
CHINES
60 PSF
18
COMPACT SOIL
FOOTING TRENCH
SECTION A-A
ATTACH
TEMPLATE
TYPICAL FRAMING LAYOUT
NO SCALE
TYPICAL BRACE,
(FRAME AS REQUIRED)
A
A
GRAPHIC SCALE
0
1'
2'
3'
4'
5'
10'
15'
3/8" = 1'-0"
0
1'
2'
3'
4'
5'
1" = 1'-0"

Figure 7-24. —Foundation and floor slab layout for a 20' by 48' rigid frame building.

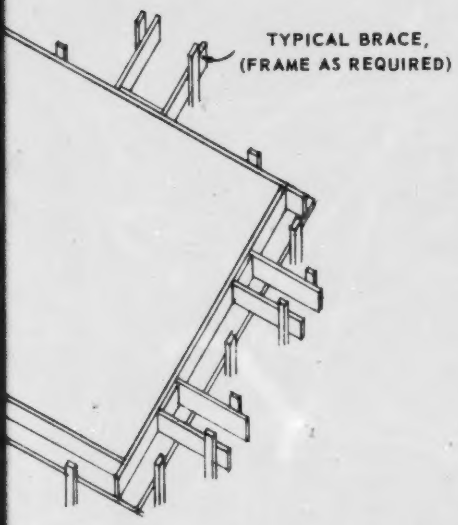
THREE BUILDINGS IN MULTIPLE

	HEAVY-DUTY SLABS ARE REQUIRED:			
	6 INCH SLAB AND FND.		1416	
1	LUMBER, 2 X 6 S4S (FORMS)	BF		450
2	NAIL, DOUBLE HD. GALV. 8D	LB		4
3	WIRE, FABRIC REINF. 6 X 6 X NO. 6	RL		2
4	CEMENT, 1-A EXPORT	BG		190
5	NAIL COMMON BRITE 12D	LB		5
	8 INCH SLAB AND FND.		1417	
1	LUMBER, 2 X 8 S4S (FORMS)	BF		200
2	LUMBER, 2 X 6 S4S (FORMS)	BF		350
3	NAIL, DOUBLE HD. GALV. 8D	LB		5
4	WIRE, FABRIC REINF. 6 X 6 X NO. 6	RL		2
5	CEMENT, 1-A EXPORT	BG		225
6	NAIL COMMON BRITE 12D	LB		5
	12 INCH SLAB AND FND.		1418	
1	LUMBER, 2 X 6 S4S (FORMS)	BF		1200
2	NAIL, DOUBLE HD. GALV. 8D	LB		7
3	WIRE, FABRIC REINF. 6 X 6 X NO. 6	RL		4
4	CEMENT, 1-A EXPORT	BG		300
5	NAIL COMMON BRITE 12D	LB		5

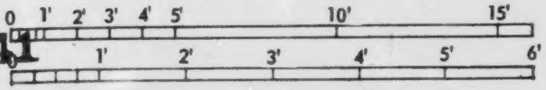


YPICAL FRAMING LAYOUT

NO SCALE



GRAPHIC SCALE



NOTES:

1. SUGGESTED LAYOUT SUBJECT TO APPROVAL OF BASE COMMANDER
2. SEE LATEST EDITION NAVFAC P-103 FOR STOCK NUMBERS AND SHIPPING QUANTITIES.

SYM	DESCRIPTION	BY	DATE	APPD

REVISIONS

FUNCTIONAL COMPONENT ASSEMBLY NO. 1415 1416 1417 1418

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
MATERIEL DEPARTMENT
U. S. NAVAL CONSTRUCTION BATTALION CENTER
PORT HUENEME, CALIFORNIA

	ARCH	ELEC	MECH
DSGN			
DRW	SADLER	5-67	
CHK	J.E.		
DRFTG. BR. MGR.			
PROJ DIR. Gene Wyrick			
MOBL DIR.			

ADVANCED BASE

20 x 48 RIGID FRAME BUILDING
FOUNDATION AND FLOOR SLAB

ARCH ELEC MECH

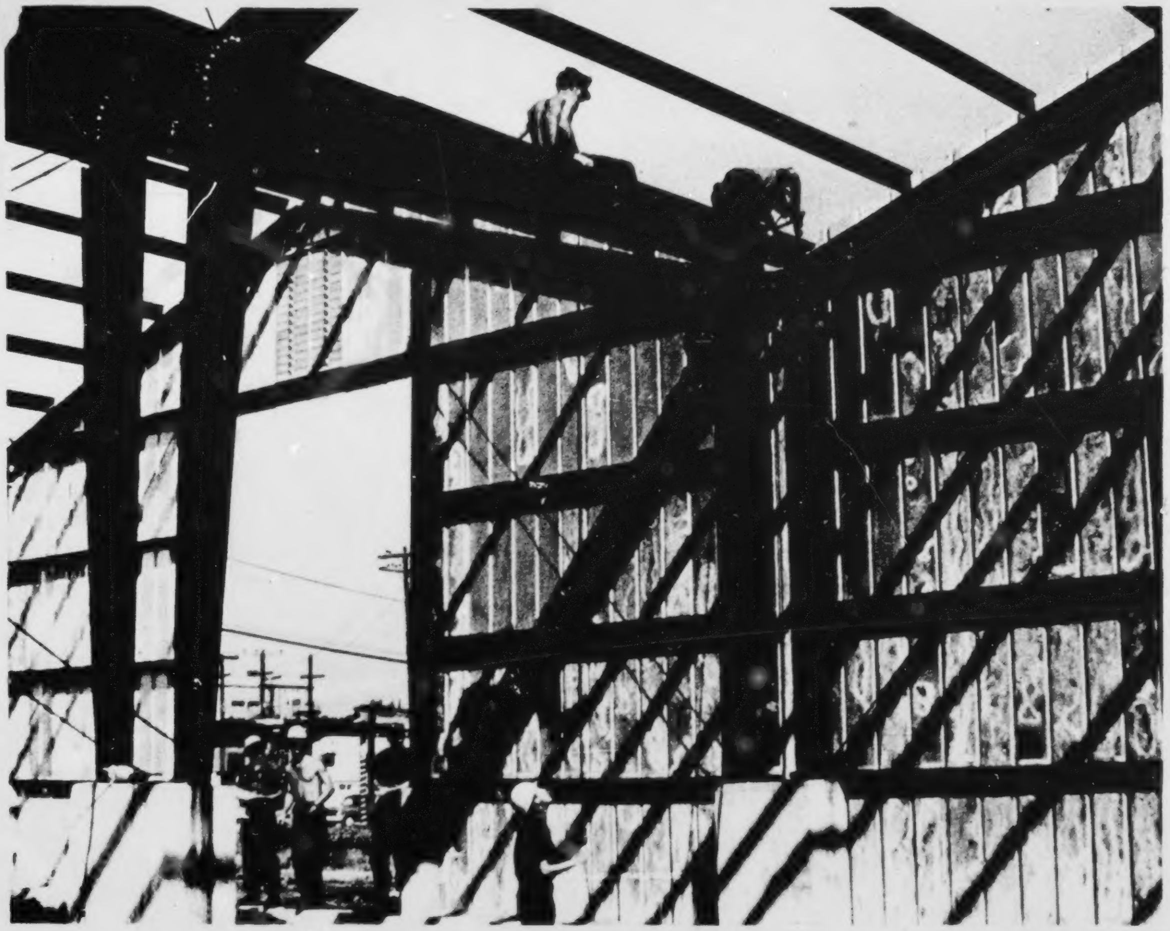
APPROVED
FOR COMMANDER NAVFAC
DATE 6/30/67

BUILDING 1109727
REFERENCE DWGS.

SATISFACTORY TO
DATE ______ BY ______

SCALE AS NOTED
SK. NO. 67111
SH. ___ OF ___
NAVFAC DRAWING NO. 1109728

frame building.



117.409

Figure 7-25. –Erecting Pascoe buildings side-by-side.

increase the length and width of prefabricated buildings but also to increase their height.

In addition to the usual reasons for stressing the importance of a square and level foundation, there is an additional reason peculiar to the erection of a prefabricated structure. Prefabricated parts are designed to fit together without forcing. If the foundation is even slightly out of square and/or level, many of the parts will not fit together as designed. Being familiar with the principles of form design, the design of concrete mixtures, and the use of NAVFAC Drawings and Specifications (discussed earlier in this book), the foundation and floor slab layout (to include modifications when required) should prove to be no problem for you.

CHAPTER 8

HEAVY CONSTRUCTION

One of your tasks as a Builder First Class or Chief may be to direct job operations involving heavy construction. In a broad sense, heavy construction means any construction which involves the use of massive, large-dimension structural members or large quantities of heavy materials.

This chapter covers such aspects of heavy construction as pile driving, shoring, caisson and cofferdam construction, and the types and uses of harbor protection structures. Information is also included on the transportable sawmill which can be used to supply timbers and dimensional lumber for heavy construction.

PILES

The principal structural members in many types of waterfront structures are PILES, a pile being a wood, steel, or concrete structural member which is driven into the ground. A vertically placed pile which sustains a vertical downward pressure is called a BEARING pile. Bearing piles may be used to transfer a load through a soft soil to an underlying firm layer of soil or rock. They may also be used to distribute a load through relatively soft soils which are not capable of supporting concentrated loads. Bearing piles are also used in situations in which it is likely that a shallow foundation may be washed away, as in the case of bridge piers.

Bearing piles fall into two main classes: the end-bearing pile and the friction pile. An end-bearing pile is driven through a very soft soil to an underlying firm material and the load is transmitted from the top of the pile to the tip and then the firm underlying material. The friction pile is driven into a soil of fairly uniform consistency and the tip is not seated into a hard layer. The load is transferred from the tip to the pile length and the friction between the pile and the material prevents the pile from sinking and supports the load. A pile which is set at an angle to sustain a diagonal pressure is called a BATTER pile. Piles which are equipped for edge-joining and which are driven edge-to-edge to form a wall which sustains a lateral (horizontal) pressure, are called SHEET piles.

All piling materials are important, but timber piles are most important. Steel piling ranks next in importance, especially where deliberate construction is planned to accommodate heavy loads or where the foundation is expected to be used over a long period of time. Steel is best suited for use as bearing piles when piles must be driven under the following conditions:

When piles longer than 80 feet are required;

Where column strength is required which exceeds the compressive strength of timber;

To reach bedrock for maximum bearing surface through overlying layers of partially decomposed rock;

To penetrate layers of coarse gravel or soft rock, such as coral; or

To attain greater depth of penetration for stability. An example of this is driving in rock-bedded and swiftly flowing streams where timber piles cannot be driven deep enough for stability.

Concrete and composite piles are used less frequently and require material and equipment not normally available through military supply channels. These are used most frequently where local materials are readily available whereas standard military piling would have to be received in large quantities from CONUS. Interlocking steel sheet piling is most often used in military construction, but field manufactured concrete sheet piling or various types of expendent sheet piling is used when local materials are available.

As you will soon realize, many factors influence the choice of pile type to be used on a given project. In DELIBERATE construction, full weight should be given to the factors listed below (and others, if applicable) in making the selection.

Anticipated pile loads.
Anticipated length of piles and ease of adjusting length, if necessary.
Soil conditions existing at the site.
Ground water conditions existing at the site.
Availability of materials.
Availability of equipment for handling and driving piles.
Time available for construction.
Degree of permanence required and exposure conditions for completed structure.
Physical properties of available pile types.
Accessibility of site and transporation facilities.
Comparative costs.

In HASTY construction, full use is made of any and all readily available materials that can be used to construct a pile foundation capable of supporting the superstructure and maximum load during the short-term period for which use of the structure is intended. The tactical situation and accompanying emphasis placed upon the economy of time and the minimizing of the construction effort will dictate whether construction is of hasty or deliberate nature.

TIMBER BEARING PILES

Timber bearing piles are usually straight tree trunks cut off above ground swell, with branches closely trimmed and bark removed. Occasionally, sawed timbers may be used as bearing piles.

A good timber pile has the following characteristics:

Free of sharp bends, large or loose knots, shakes, splits, and decay.

A straight line between centers of butt and tip lies within the body of the pile.

A uniform taper from butt to tip.

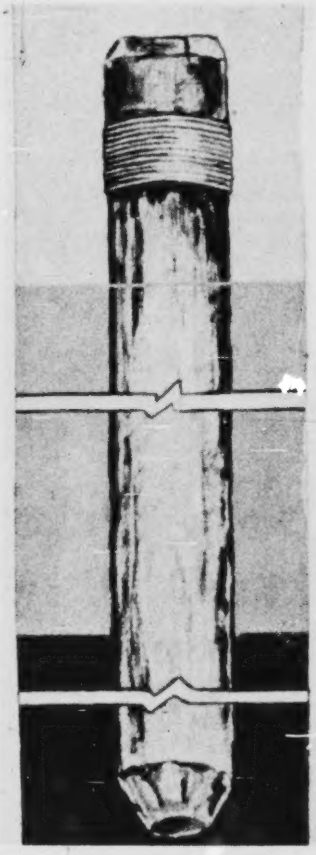
Limiting cross section dimensions of timber used as piles are:

Piles shorter than 40 feet–tip (small end) diameters, 8 to 11 inches, and butt (large end) diameters 12 to 18 inches.

Piles longer than 40 feet–tip diameters, 6 to 8 inches, and butt diameters, 13 to 20 inches. The butt diameter must not be greater than the distance between the pile leads.

Timber piles usually are driven with the tip down.

A typical timber bearing pile is shown in figure 8-1.



133.3

Figure 8-1. –Typical timber bearing pile.

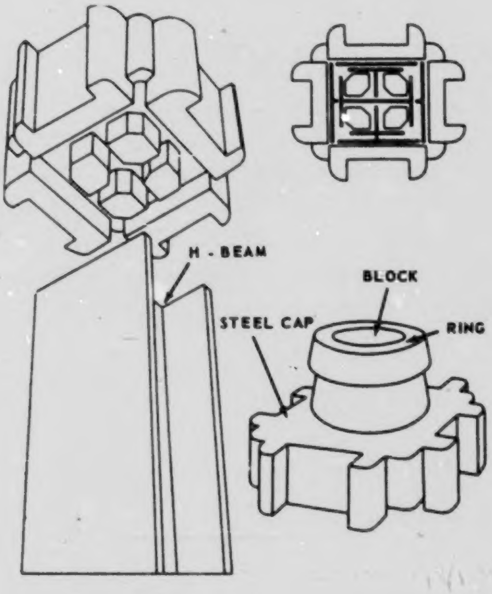
STEEL BEARING PILES

The two most common types of steel bearing piles are the H-PILE and the PIPE PILE. The H-pile is a steel beam with a cross-section shaped like an H; it is driven with a special pile-driving cap as shown in figure 8-2. The pipe pile is a steel pipe. An OPEN-END pipe pile is open at the bottom; a CLOSED-END pipe pile is closed at the bottom.

CONCRETE BEARING PILES

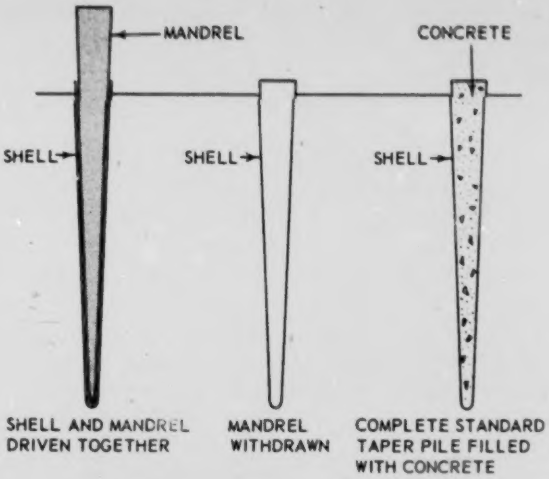
A concrete bearing pile may be CAST-IN-PLACE or PRECAST. A cast-in-place concrete pile may be a SHELL type or a SHELL-LESS type. A shell type cast-in-place pile is constructed as shown in figure 8-3. As you can see, a steel core called a MANDREL is used to drive a hollow steel shell into the ground. The mandrel is then withdrawn and the shell is filled with concrete. If the shell is strong enough, it may be driven without a mandrel.

A shell-less cast-in-place concrete pile is made by placing the concrete in direct contact with the earth. The hole for the pile may be made by driving a shell or a mandrel and shell, or it may be simply bored with an EARTH AUGER. If a mandrel and shell are used, the mandrel, and usually also the shell, are removed before the concrete is poured. In one method, however, a cylindrical mandrel and shell are used, and only the mandrel is removed before the concrete is poured. The concrete is poured into the shell, after which the shell is extracted.



133.206

Figure 8-2. —Steel H-pile and special cap for driving.


MANDREL
CONCRETE
SHELL
SHELL
SHELL
SHELL AND MANDREL DRIVEN TOGETHER
MANDREL WITHDRAWN
COMPLETE STANDARD TAPER PILE FILLED WITH CONCRETE

45.526

Figure 8-3. —Shell type cast-in place concrete pile.

Casting in place is not usually feasible for concrete piles used in waterfront structures. Concrete piles for waterfront structures are usually PRECAST. Precast concrete piles are usually either square or octagonal in cross-section: square-section piles run from 6 to 24 in. square. Concrete piles more than 100 ft long have been cast but piles longer than 50 or 60 ft are usually too heavy for handling.

SHEET PILES

Sheet piles are special shapes of interlocking piles made of steel, wood, or formed concrete, which are used to form a continuous wall to resist horizontal pressures resulting from earth or water loads, and for other purposes. The term SHEET PILING is used interchangeably with sheet piles. In selecting the type for a particular installation, consideration should be given to the advantages of each from a standpoint of cost, durability, strength, availability, salvage value, and foundation conditions. A few common uses of sheet piles are as follows:

To resist earth (and water) pressure as a part of a temporary or permanent structure. For example, steel sheet piling is widely used to form the BULKHEADS which are an integral part of many waterfront structures, such as wharves and docks. RETAINING WALLS may be built of sheet piling.

A major use of sheet piles is in the construction of COFFERDAMS, which are built to exclude water and earth from an excavation so that construction can be carried out more easily.

Sheet piles are used in the sheathing of trenches; they are usually braced in such applications.

Sheet piles may be used to form small dams and, more frequently, to form cutoff walls beneath water-retaining structures in order to retard the flow of water through the foundation.

Sheet piles may be used in the construction of piers for bridges and left in place. For example, a pier may be formed by driving steel sheet piling to form a square or rectangular inclosure, excavating the material inside to the desired depth, and then filling the enclosed space with concrete.

Groins and sea walls may be formed from sheet piles.

TIMBER SHEET PILING

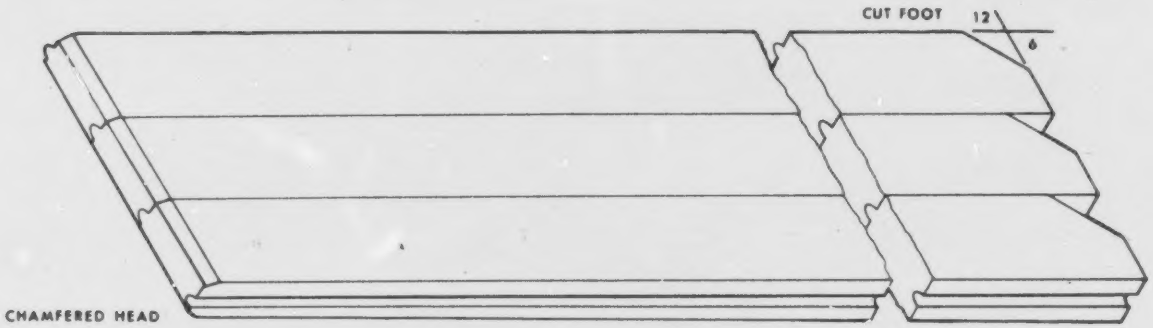
When an abundance of timber is available in a theater of operations and the supply of steel sheet piling is limited, timber sheet piling may be fabricated for temporary structures and to resist light lateral pressures. Where marine borers are active or for permanent type structures, timber sheet piling is creosoted. Tongue and groove piling of single thickness (figure 8-4) is usually used where only earth pressures are involved, as in excavating a trench above the water table. For larger pressures and watertightness, fabricated piling such as Wakefield (figure 8-5) is used. Where only larger pressures are anticipated, heavy timber piling (figure 8-6) is used.

STEEL SHEET PILES

The edges of a steel sheet pile are called interlocks, because they are shaped for locking the piles edge-to-edge. The part of the pile between the interlocks is called the WEB. Piles are manufactured in 5 standard section shapes: STRAIGHT-WEB (figure 8-7), SHALLOW-ARCH (figure 8-8), DEEP-ARCH (figure 8-9), Z-SECTION (figure 8-10), and CORNER-SECTION figure 8-11). Sections vary slightly in shape with different manufacturers, each of whom has a particular letter and number symbol for each section he manufactures.

CONCRETE SHEET PILES

Concrete sheet piles are reinforced precast concrete piles of rectangular cross section, with tongue-and-groove interlocks. A working drawing for a concrete sheet pile is shown in figure 8-12.



133.394

Figure 8-4. —Tongue and groove timber sheet piling.

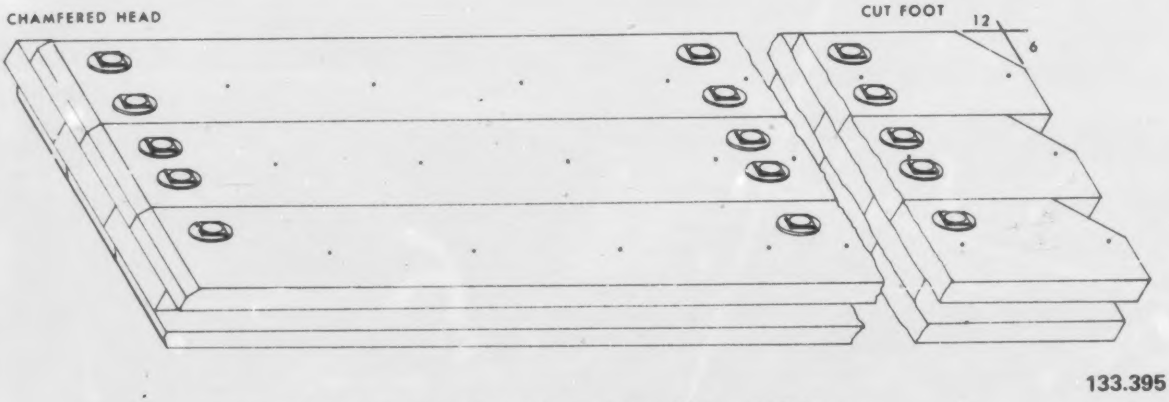


Figure 8-5. —Fabricated timber sheet piling, wakefield type.

PILE DRIVING EQUIPMENT

In order to drive piles, the following equipment is needed under normal operating conditions. A piledriver—either a crane-shovel with standard pile-driving attachment or the steel-frame, skid-mounted piledriver—is used to support the leads (hammer guides), raise the pile in the leads, and operate the hammer. A pile-driving hammer delivers the driving blow. Piledriving leads are used to support and align the pile during driving, and to control the lateral motion of the hammer. Additional support equipment for handling stockpiled piling and for straightening, cutting, capping, and bracing piles must be available. Under special driving conditions, other standard and fabricated equipment may be required.

The principal types of pile-driving hammers used by SEABEES are the DROP HAMMER, the SINGLE and DOUBLE ACTING AIR or STEAM, and the DIESEL HAMMER.

A drop hammer is a block of steel that is set into a set of leads and raised and dropped onto the butt of a pile. Weights of hammers will vary from 1500 lbs to 12,000 lbs depending on the type of piles being driven. The hammer should weigh 1-1/2 to twice the weight of the pile being driven. The height of fall of the hammer should be from 6 to 15 feet. Blow of the hammer will vary from 15 to 20 blows per minute. A driving cap is installed on most hammers to keep the pile from brooming. The driving cap is a block of steel that slips over the head of a pile with a cushion block of wood fit into the top of the driving cap onto which the hammer falls, as

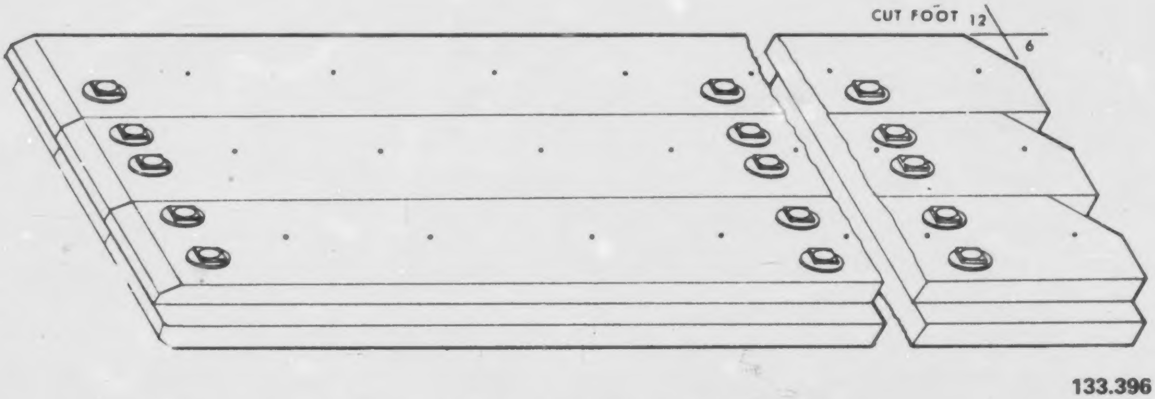
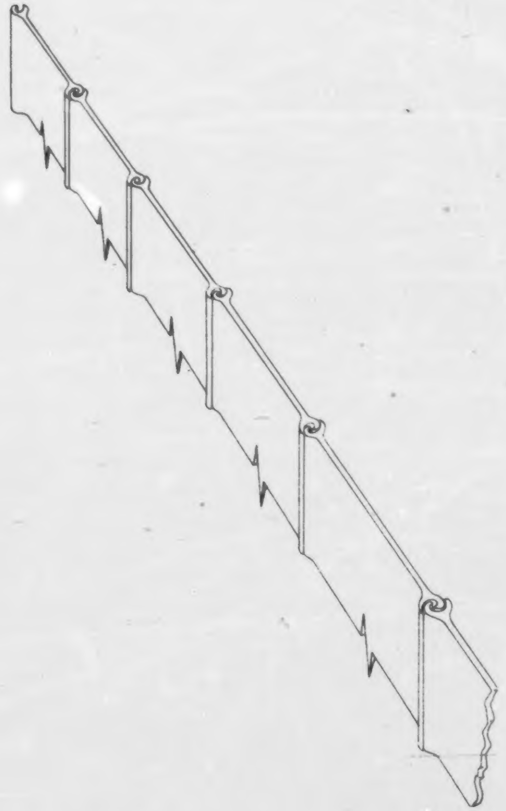
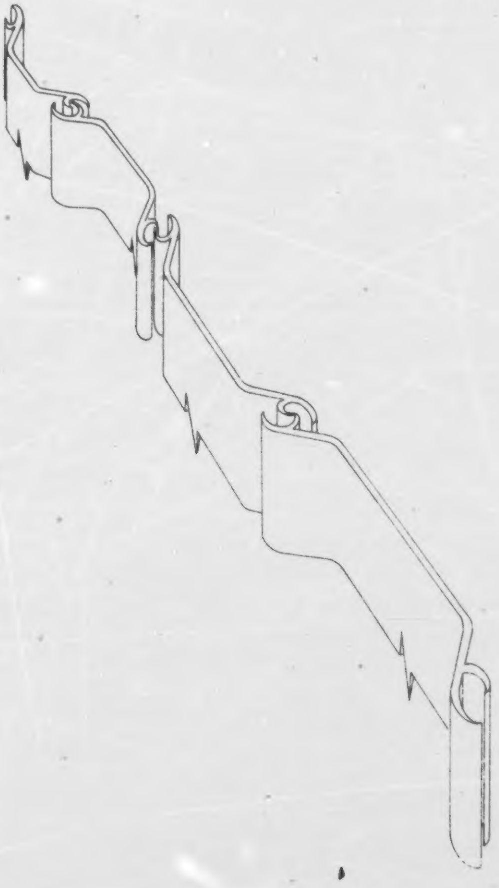


Figure 8-6. —Timber sheet piling fabricated from heavy timbers.



133.397

Figure 8-7. –Standard straight-web steel sheet pile.



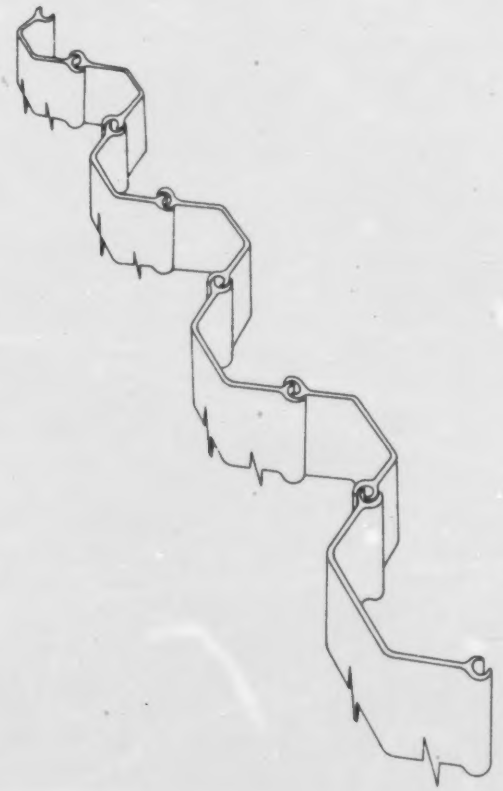
133.398

Figure 8-8. –Standard shallow-arch steel sheet pile.

shown in figure 8-13. Under expedient conditions a log hammer or concrete may be used. The advantage of the drop hammer is that it is cheap and quickly assembled. The disadvantage of the hammer is that it is slow and inefficient on large jobs.

Single acting air or steam hammers consist of a stationary cylinder and a moving part called the ram which includes the piston and striking lead. The single acting hammer is designed so that the piston is raised by air or steam pressure and the fall is induced by gravity. The sizes of the single acting hammer will range from 3000 lbs ram to 14,000 lbs ram, and from 50 to 80 blows per minute–stroke 32 inches to 36 inches. The air or steam requirements for the single acting hammer is 80 psi (pounds per square inch), with a minimum size hose of 2 inches. In lubrication of the hammer, an oiler is attached to the hose and oil is regulated into the air hose and onto the piston.

The double acting air or steam hammer piston and ram is raised by air or steam pressure and is also forced down by pressure. The size of the hammer will vary from 5000 lbs to 10,000 lbs ram, and three (3) 3/4 inch to 24 inch stroke, and from 80 to 550 blows per minute depending on the hammer (it is the fastest hammer in use). Steam or pneumatic pile hammers are shown in figure 8-14. Figure 8-15 shows a pile being driven with a pneumatic hammer. The operating



133.399

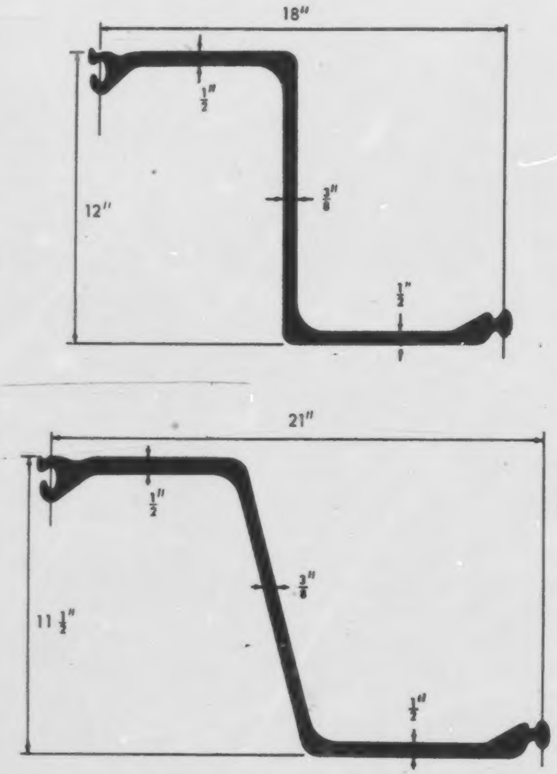
Figure 8-9.—Standard deep-arch steel sheet pile.

pressure for air and steam hammers is usually about 100 psi with a volume of 100 to 600 CFM feed through a 2 inch hose. The driving head will vary from job to job depending on what type of piles you drive. Special driving caps will be used for sheet piling and steel pilings. The double acting hammer generally is used to drive light or average weight piles into soils of average density because the rapidity of blows tends to keep the pile in motion and thereby reduces the effect of friction. The double acting hammer is faster than the single acting hammer because of its lighter ram and shorter strokes.

The diesel pile hammer is about twice as fast as a conventional pneumatic or steam hammer of comparable size and weight. A conventional pneumatic hammer requires a 500-cu ft/min compressor to operate, while the diesel is a self-contained unit that is constructed in sizes capable of delivering up to 22,400 ft lbs of energy per blow.

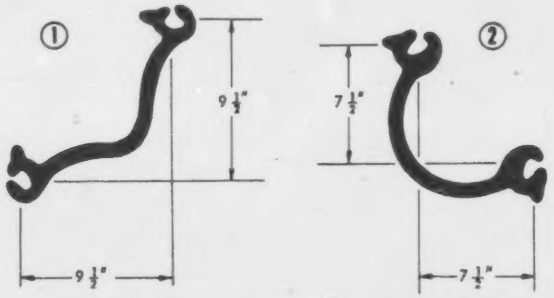
The McKiernan-Terry pile hammer illustrated in figure 8-16 is made up of a cylinder, ram-piston, fuel pump, built-in fuel tank (which holds supplies for three days without refueling), lubricant oil tank (which holds lubricant supplies for three days), and an inertia oil pump that mechanically lubricates during operation.

Pile driving leads serve as tracks along which the hammer runs and as guides for positioning and steadying the pile during the driving. Leads are constructed of wood and steel. Most pile driving is carried out with crawler or mobile cranes for which pile driving attachments are a part of standard equipment. Adapters connect the leads of the pile driver to the point of the crane boom, all leads and adapters have a standard bolt-hole layout. Pulleys are attached to the point of the crane boom and cables run



133.211

Figure 8-10. —Z-sections.

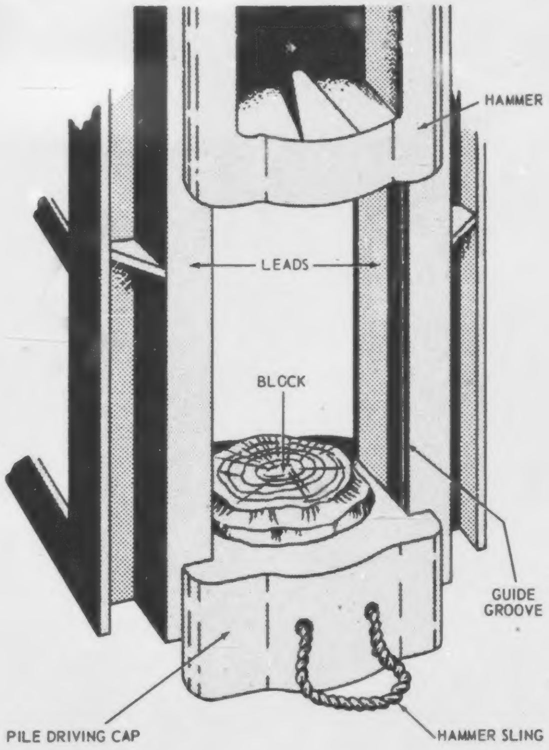

①
9½"
9½"
②
7½"
7½"

133.212

Figure 8-11. –Two standard corner sections.

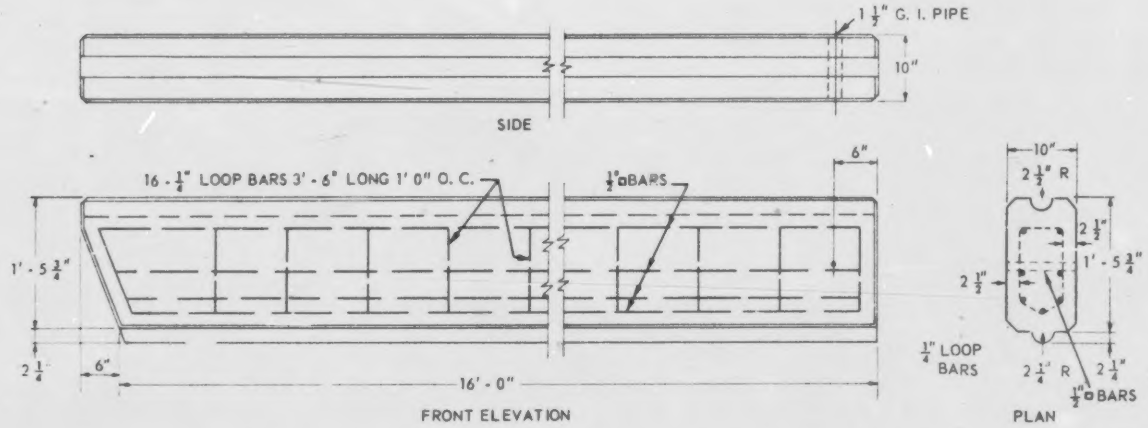
from the crane through the pulleys for the hammer and lifting piling. A ladder is attached to the back of the leads so men can guide the piles into place and unhook the cable from the piles. Catwalk (telescoping)–the foot of the leads is braced with a telescoping catwalk connected to the base of the boom. By varying the length of the catwalk and the angle of the boom, the leads may be held in a vertical position for driving bearing piles or may be sloped for driving batter piles, as shown in figure 8-17. The moonbeam is used on a skid rig. It is a slightly curved beam placed transversely at the forward end of the skid frame to regulate side batter, as shown in figure 8-18.

Many types of power units can be used for lifting piling and hammer. The unit used must


HAMMER
LEADS
BLOCK
GUIDE GROOVE
PILE DRIVING CAP
HAMMER SLING

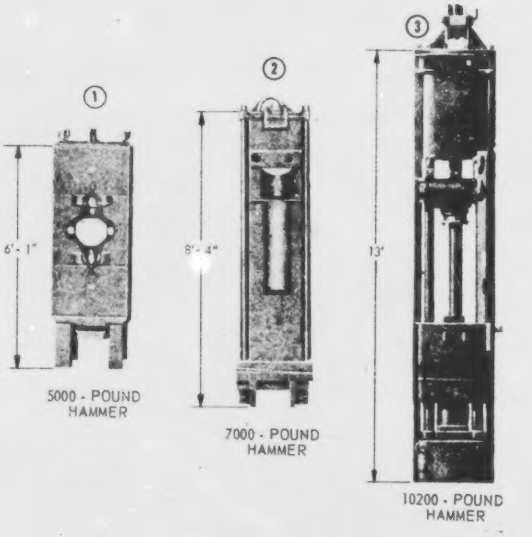
133.214

Figure 8-13. –Cap for driving timber piles by drop hammer.


1½" G. I. PIPE
10"
SIDE
6"
16 - ¼" LOOP BARS 3' - 6" LONG 1' 0" O. C.
½"□BARS
1' - 5¾"
2¼"
6"
16' - 0"
FRONT ELEVATION
10"
2½" R
2½"
1' - 5¾"
2½"
¼" LOOP BARS
2¼" R
2¼"
½"□BARS
PLAN

133.213

Figure 8-12. –Concrete sheet pile.



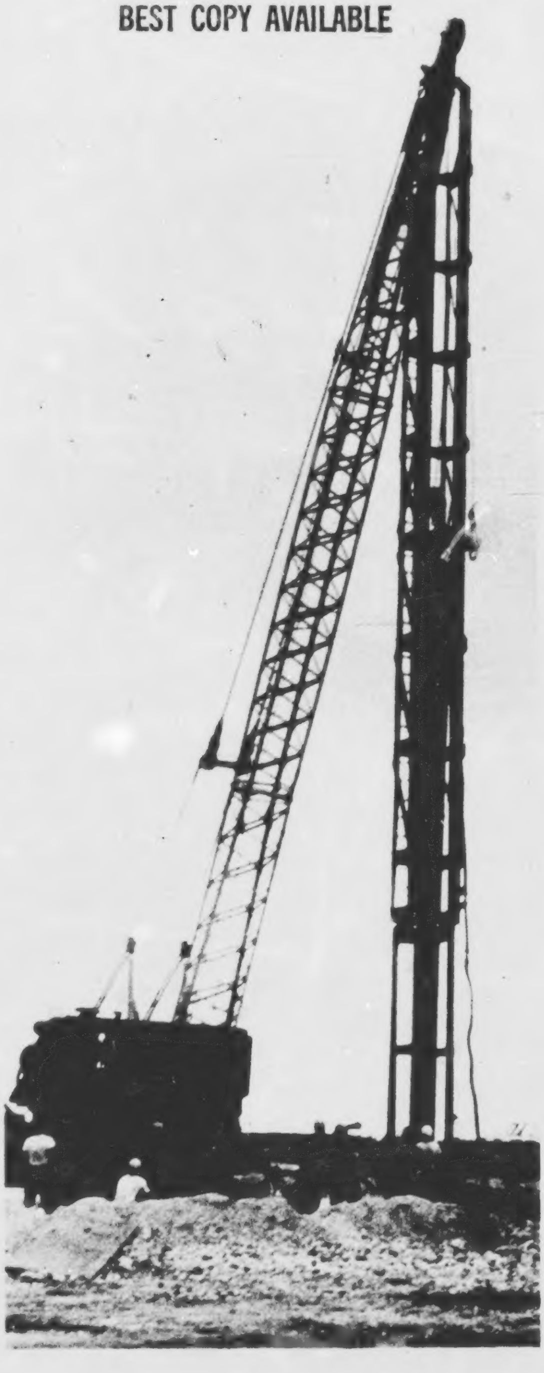
133.215
Figure 8-14. —Steam or pneumatic pile hammers.

have at least two times the lifting power of the weight of the hammer.

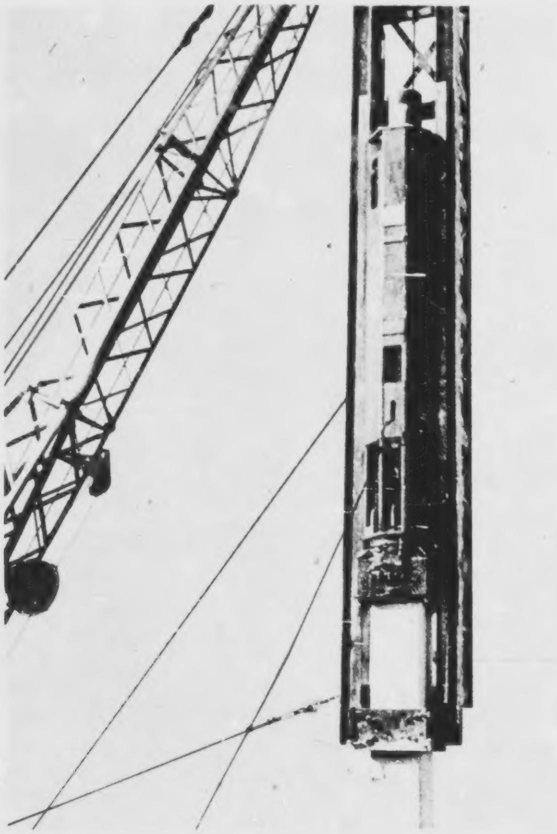
PILE-DRIVING OPERATIONS

When bearing piles are driven on land the position of each pile is usually located by the Engineering Aid and marked with a stake. A common method of locating the positions of a series of pile bents driven in water is a wire rope long enough to stretch between the abutments and marked with pieces of tape, spaced in accordance with the prescribed or calcuated distance between bents.

After the first bent is driven, piles in subsequent bents may be located by the use of a floating TEMPLATE like the one shown in figure 8-19. Pairs of BATTENS, spaced in accordance with the specified spacing between piles in a bent, are nailed across a pair of timbers, spaced in accordance with the specified spacing between bents. The parts of each batten lying beyond the timbers are hinged for raising. The template is lashed to the outer piles in the bent already driven by means of a pair of wire ropes, equipped with turnbuckles as shown. After the piles in the new bent are driven, the hinged parts of the battens are raised, the wire ropes are let go, and the template is floated out from between the bents.

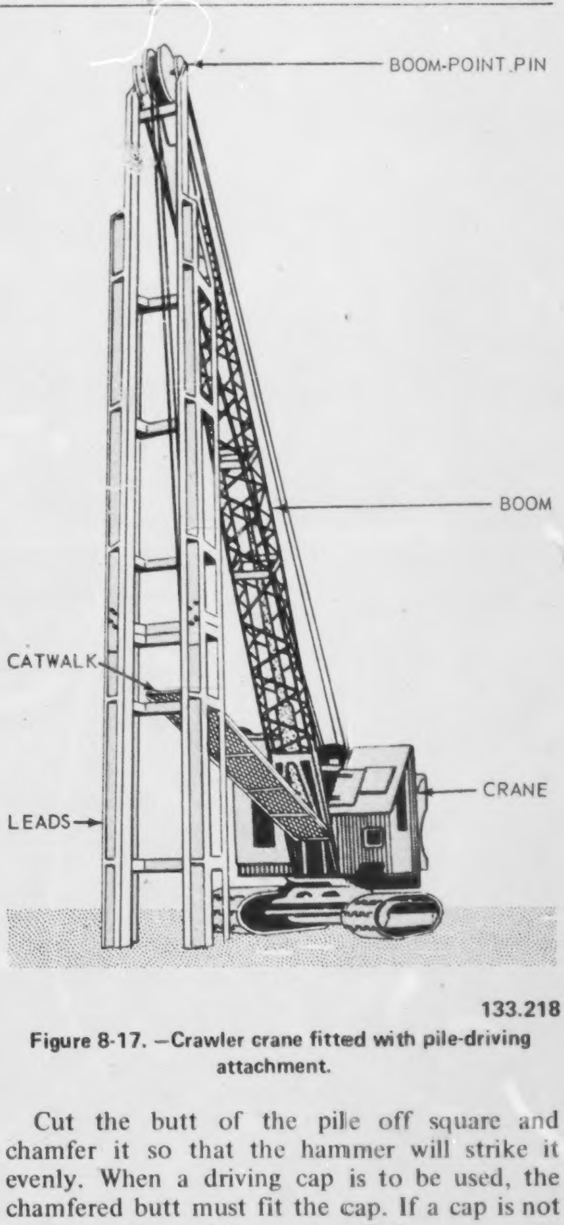


133.216
Figure 8-15. —Pile being driven with a pneumatic hammer.



133.217

Figure 8-16. –Diesel hammer.



133.218

Figure 8-17. –Crawler crane fitted with pile-driving attachment.

Piles can be driven either tip or butt down; they may be driven butt first if a large bearing area is required or if the pile is to resist an upward force.

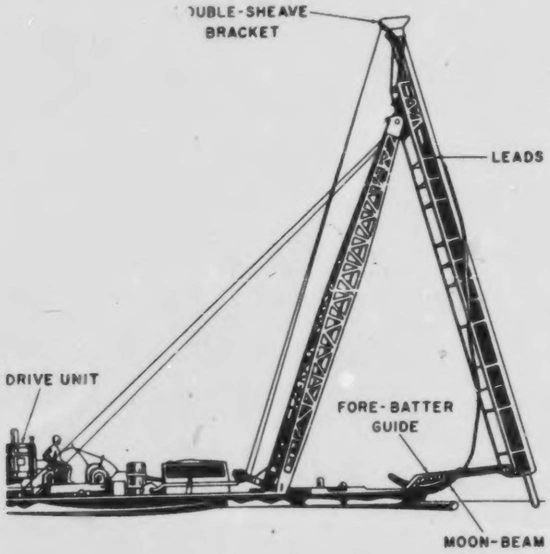
PREPARATION OF BEARING PILES FOR DRIVING

Before piles are driven, they must be properly prepared to obtain the greatest efficiency in driving and to protect the pile from damage.

Timber Piles

Timber piles are susceptible to damage during driving, particularly under hard driving conditions. To protect the pile against damage, the following procedures may be taken:

Cut the butt of the pile off square and chamfer it so that the hammer will strike it evenly. When a driving cap is to be used, the chamfered butt must fit the cap. If a cap is not used, or if crushing and splitting occur, in addition to chamfering the butt, the top end of the pile is wrapped with 10 to 12 turns of wire at a distance of about one diameter below the head of the pile, as shown in views 1 and 2 of figure 8-20. If a hole is bored in the butt of the pile, double wrappings are used as indicated in view 3 of figure 8-20. As an alternate method of preventing the butt of the pile from being crushed or split by the hammer blows, two



133.219
Figure 8-18. —Steel-frame, skid-mounted pile driver.

half-rings of 3/8 inch steel are clamped around the butt, as in view 4 of figure 8-20.

Cut the foot of the pile off perpendicular to its axis. When the pile is to be driven into soft or moderately compressible soil, the tip of the pile may be left unpointed. A blunt-end pile provides a larger bearing surface than a pointed-end pile when used as an end-bearing pile. When the pile is to be driven into soil that is only slightly compressible (a hard soil), the soil must be displaced and the pile sharpened so that its tip is shaped like a truncated pyramid (view 1, figure 8-20). The blunt end is usually from 4 to 6 inches square and the length of the tip is from 1-1/2 to 2 times the diameter of the foot. A crooked pile may be pointed for driving as shown in view 2 of figure 8-20. For very hard driving, steel shoes (figure 8-21) are used to protect the tip of the pile. Improvised steel shoes are shown in view 4 of figure 8-20.

Lagging is used to increase the resistance of a friction pile. Before driving the pile, long, narrow strips of wood or steel are lag screwed to the pile as shown in figure 8-22. These are attached to the lower part of the pile from approximately 12 inches above the tip to the limits of the depth that the pile is expected to penetrate. The extra surface area increases the pile's load carrying capacity, but tends to make it more difficult to drive.

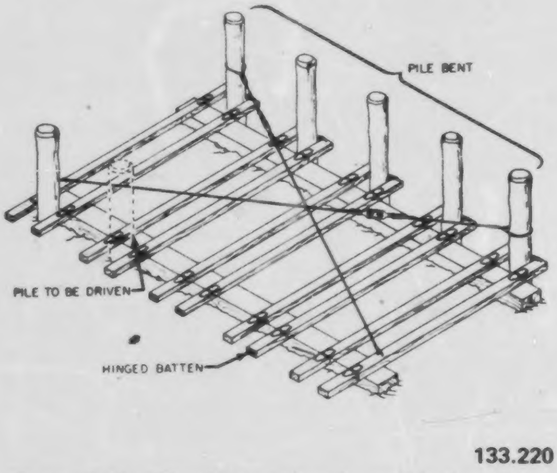
Steel Piles

To distribute the load on the bearing end of steel H-pile the points of the piles may be built up by adding welded or riveted plates. The thickness should be built up to 2-1/2 or 3 times the original thickness for a height of 2-1/2 to 3 times the width of the member. Typical built-up points are shown in figure 8-23.

In the more plastic compressible soils, the load bearing capacity of a steel friction pile may be increased in the same manner as for timber piles, that is, by the use of lagging. It is attached by bolts or welded as shown in figure 8-24.

DRIVING BEARING PILES

The four major steps in driving a bearing pile with a drop-hammer rig are as follows. (1) The pile driver is brought into position over the pile location, and the hammer and cap are run up to the top of the leads. (2) The pile is brought up to the foot of the leads, the pile whip attached, and the pile is hoisted into the leads. (3) The hammer and cap are lowered onto the top of the pile, and the cap is detached from the hammer. (4) The hammer is raised and dropped to drive the pile.



133.220
Figure 8-19. —Floating template for positioning piles.

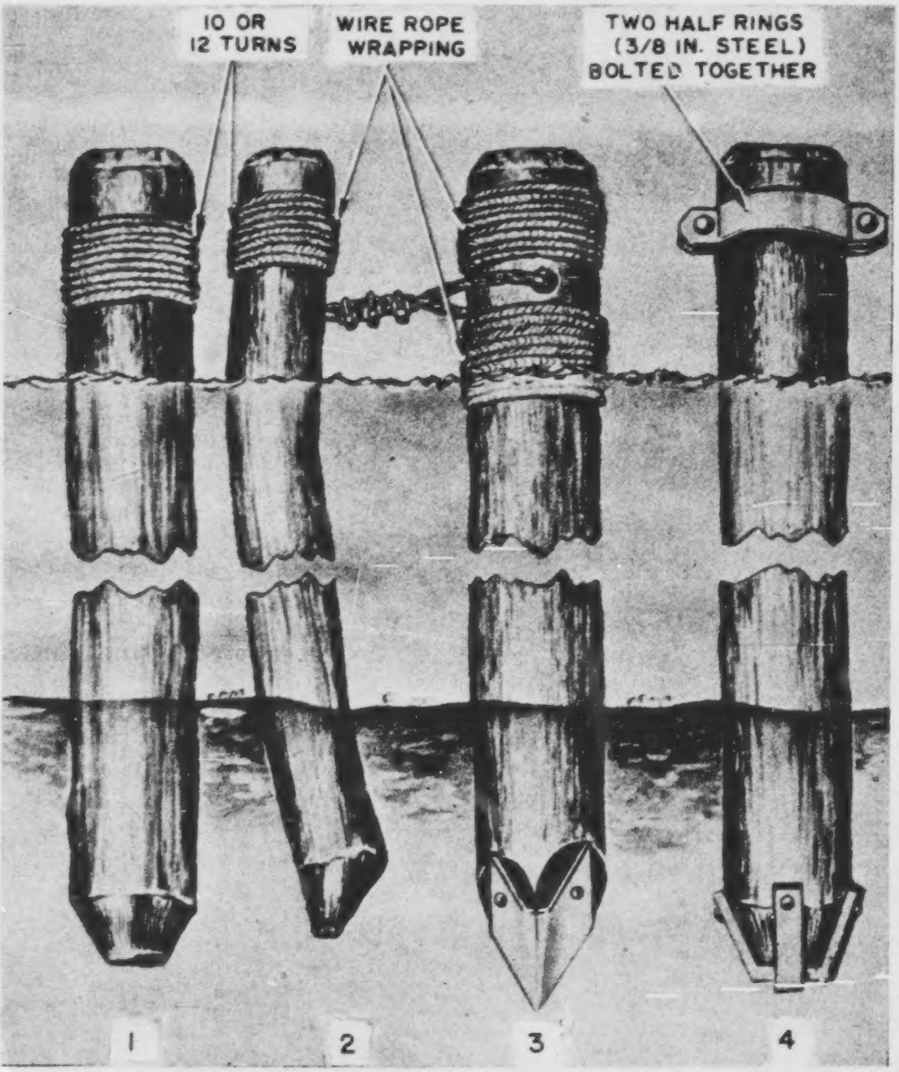


Figure 8-20.–Preparation of timber piles for driving.

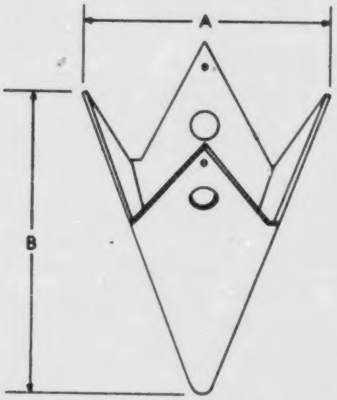
Driving should be started slowly with a drop hammer; the hammer should be raised only a few inches until the pile is firmly set. The height of the drop should then be gradually increased to a maximum of 10 or 15 ft. Blows should be applied as rapidly as possible, to keep the pile moving and prevent resistance caused by inertia and friction.

With the steam or pneumatic hammer the first blows should be given under reduced pressure, until the pile is firmly set. Pressure should then be gradually increased to the maximum.

DRIVING BATTER PILES

The prescribed angle for a batter pile is indicated on working drawings as shown in figure 8-25. The angle is obtained by setting the leads, which is done on a crane rig by adjusting the length of the catwalk. On a steel-frame, skid-mounted rig it is done by adjusting the length of the fore-batter guide, or by adjusting the position of the leads on the moonbeam, or both.

A certain amount of figuring is required, both for setting the leads and for locating the point of



SHOE	FOR PILES (Diameter)	A (inches)	B (inches)
No. 1	6 in. to 9 in.	$7\frac{5}{8}$	$9\frac{3}{4}$
No. 2	8 in. to 11 in.	9	$11\frac{1}{2}$

117.411

Figure 8-21. —Steel shoes for timber piling.

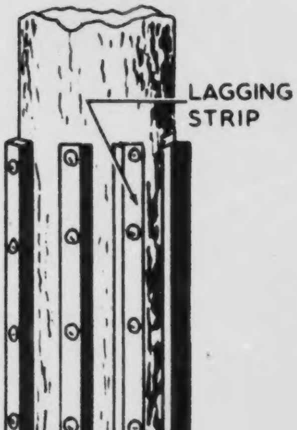
penetration of the pile. Let's take the lead-setting problem first. Suppose your leads are 65 ft high and you want to set them for a 1 in 12 (unit of run 1 foot, unit of rise 12 feet) batter. What you need to know is: How far must the foot of the leads be offset from the vertical position to get the required batter?

In this case the working drawings prescribe a unit of run of 1 for every 12 units of rise. The total rise of the leads is the height of the leads, which in this case is 65 ft. The total run of the leads must be offset from the vertical position and must therefore be the value of x in the proportional equation $1:12::x:65$, or 5-5/12 ft, or 5 ft 5 in.

The problem of locating the point of penetration of a batter pile is illustrated in figure 8-26. From the working drawings you know the location of the head of the pile and the vertical distance of the top of the pile above the ground line after the pile is driven. For a given batter, the point of penetration of the pile will be a given distance away from a point on the ground directly below the location of the head of the pile. Let's say the prescribed batter is again 1 in 12 and the vertical distance of the top of the driven pile above the ground line will be 36 ft. The distance between the point of penetration of the pile and a point on the ground directly below the location of the head of the pile must therefore be the value of x in the proportional equation $1:12::x:36$, or 3 ft.

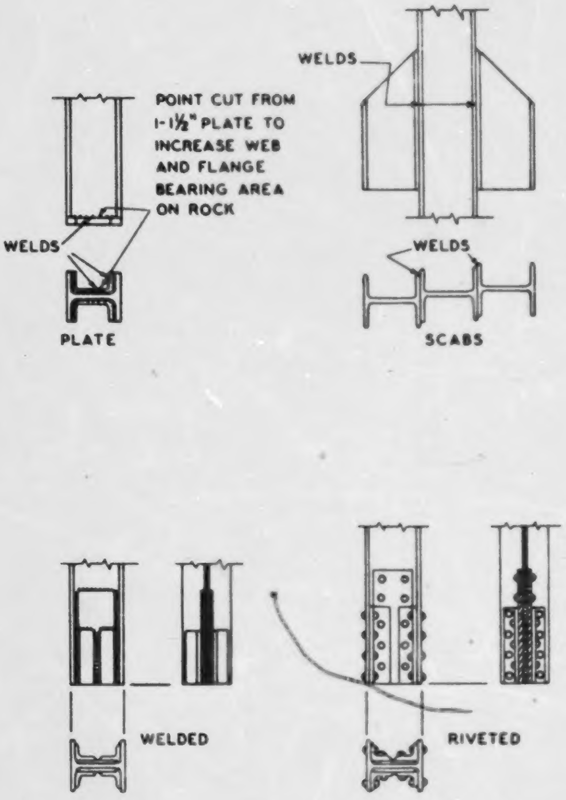
DRIVING SHEET PILES

Sheet piles are frequently driven without leads, as shown in figure 8-27; a hammer used without leads is called a FLYING hammer. The



133.400

Figure 8-22. —Lagging of a timber friction pile.


WELDS
POINT CUT FROM 1-1½" PLATE TO INCREASE WEB AND FLANGE BEARING AREA ON ROCK
WELDS
PLATE
WELDS
SCABS
WELDED
RIVETED

117.412

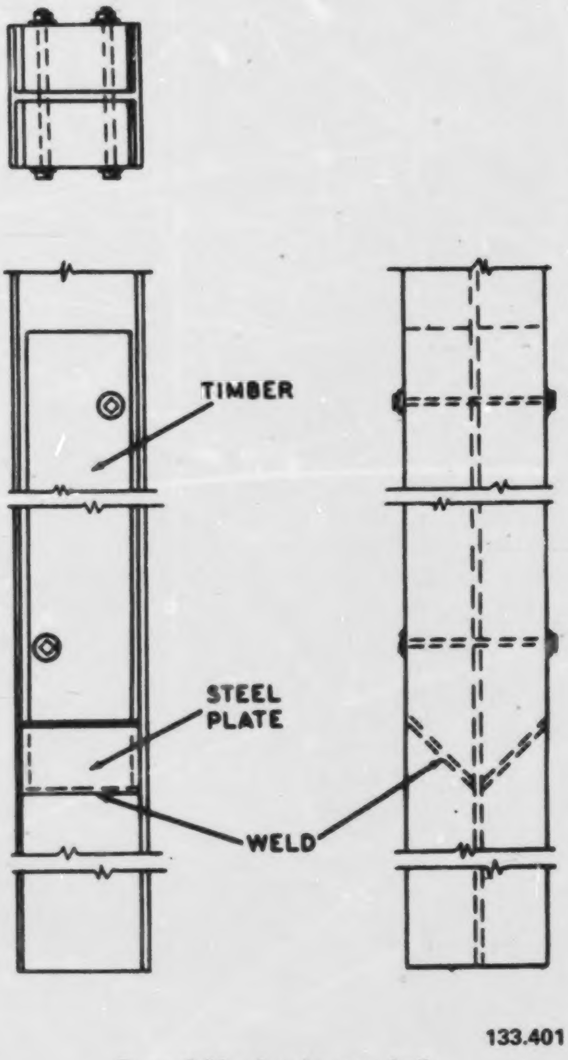
Figure 8-23. —Typical built-up points for steel piles.

drop hammer is not used to drive sheet piling. The cap of the hammer is equipped with a device which fits over the top of the pile. The crane operator slacks the hammer whip just enough to keep the hammer in contact with the pile as the pile goes down.

When sheet piles are driven with a flying hammer the piles are held upright by one or more pairs of elevated wales, supported by a braced framework of studs. The wales also guide the alignment of the piles. For piles driven in deep water, a system of floating wales is used.

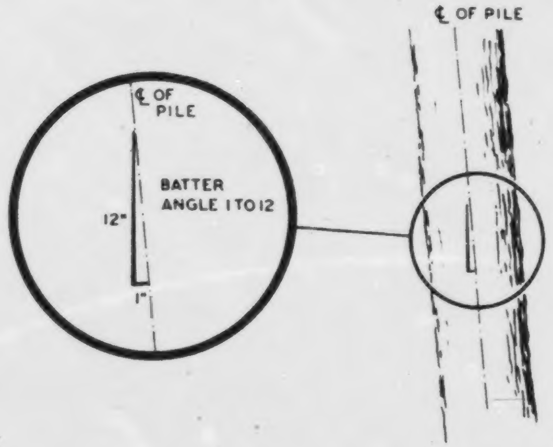
Steel sheet piles must be locked together as they are driven. After the first pile is driven, or set in place for driving, the next pile must be hoisted high enough to bring its foot level with the head of the pile already in place. A man on the head of the first pile guides the interlock on the second pile into the interlock on the first. This man, who is hoisted to the top of the pile by the pile whip, is supported by a steel STIRRUP which straddles the top of the pile.

When arch or deep-arch steel sheet piles are driven with the arch webs all extending in the same direction, the piles are said to be driven WEBS IN LINE. When the piles are driven with arch webs extending alternately in opposite directions, they are said to be driven WEBS REVERSED. In interlocking, the BALL on the interlock of one pile fits into the SOCKET on the interlock of the adjoining pile. In driving, the BALL pile is driven first and the socket pile



133.401

Figure 8-24. —Lagging a steel pile.



45.525

Figure 8-25. —Batter angle of a pile.

is fitted to it; this is called driving the piles BALL-END LEADING. If the socket pile were driven first, the socket would fill up the soil which would compact under the ball on the ball pile. This could create enough pressure to force open the socket.

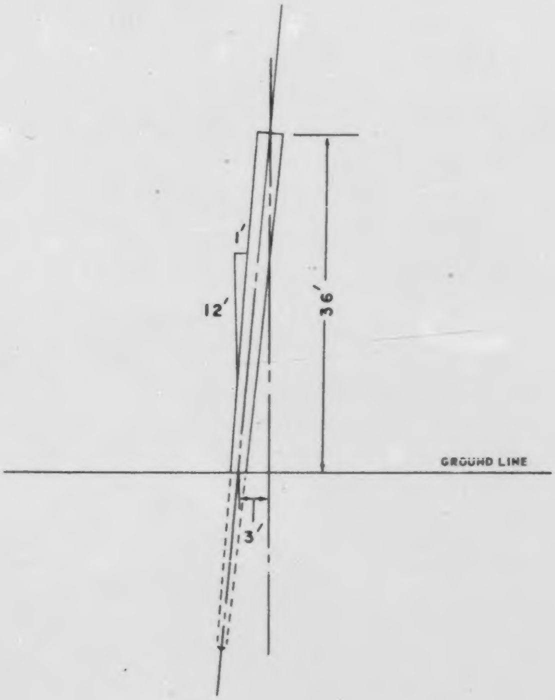
PRECAUTIONS DURING DRIVING

Very careful watch must be kept during the driving of a pile, in order to avoid damge to the pile, pile hammer, or both. Included among the precautions to be taken and danger signs to be watched for are the following:

The piledriver must be securely ballasted, guyed, or otherwise fastened down in order to prevent movement during driving. In all pile-driving operations, it is essential that the fall of the hammer be in line with the pile axis; otherwise, the head of the pile may be damaged severely, the hammer damaged, and much of the energy of the hammer blow lost.

During driving, the pile should be watched for indications of breaking or splitting below ground. If the driving suddenly becomes easier, or if the pile suddenly changes direction, it probably has broken or split; further driving then would be useless. Another pile may be driven close to the broken one, or the broken one pulled and a new one driven in its place. A pile which has failed is not used, since its bearing power cannot be counted on.

Careful watch also is kept for tendencies of the pile to spring or hammer to bounce. Springing is an excessive lateral vibration of the pile. Springing may occur when a pile is crooked, when the butt has not been squared off properly, or when the pile is not in line with the fall of the hammer. Bouncing may be due to the use of a hammer which is too light. However, it usually occurs when the butt of the pile has been crushed or broomed, when the pike has met an obstruction, or when it has penetrated to a solid footing. When a double-acting hammer is being used, bouncing may be due to the use of too much steam or air pressure. When using a closed-end diesel hammer, lifting of the hammer on upstroke of ram-piston is usually caused by too high a throttle setting; throttle control should be backed off just enough to avoid this lifting action. If the butt of a timber pile has



133.221

Figure 8-26. —Locating point of penetration for a batter pile.

133.222

Figure 8-27. –Driving sheet piles with flying hammer.

been crushed or broomed for more than an inch or so, it should be cut back to sound wood before driving is continued.

When the last 6 blows of a drop hammer or the last 20 blows of a diesel, steam, or air hammer will not drive the pile more than an average of 1/8 inch per blow, penetration has ceased because of obstruction or refusal. If the pile has been driven to refusal, further driving may crack or fracture it; effects of overdriving timber piles are shown in figure 8-28. If the lack of penetration seems to be due to an obstruction, it may be small enough so that 10 or 15 blows of less than maximum impact will drive through the obstruction and start the pile moving. For example, in driving piles in a glacial deposit, like boulder clay, a small boulder may be encountered which may be displaced or broken by a few light blows on the pile.

If the pile has encountered a firm stratum, this fact may be detected by driving a few other piles nearby. If they stop at the same elevation, it may be taken as an indication that a firm stratum has been reached.

It must be remembered that it is not always necessary to drive piles to refusal. Friction piles frequently must be driven only far enough to develop the desired load-bearing capacity. In certain types of soils, such as the very soft organic soils of a deep marsh deposit, a considerable length of pile may be necessary in order to develop adequate load capacity. Driving in such soils is frequently very easy; the pile may penetrate several feet under a single hammer blow.

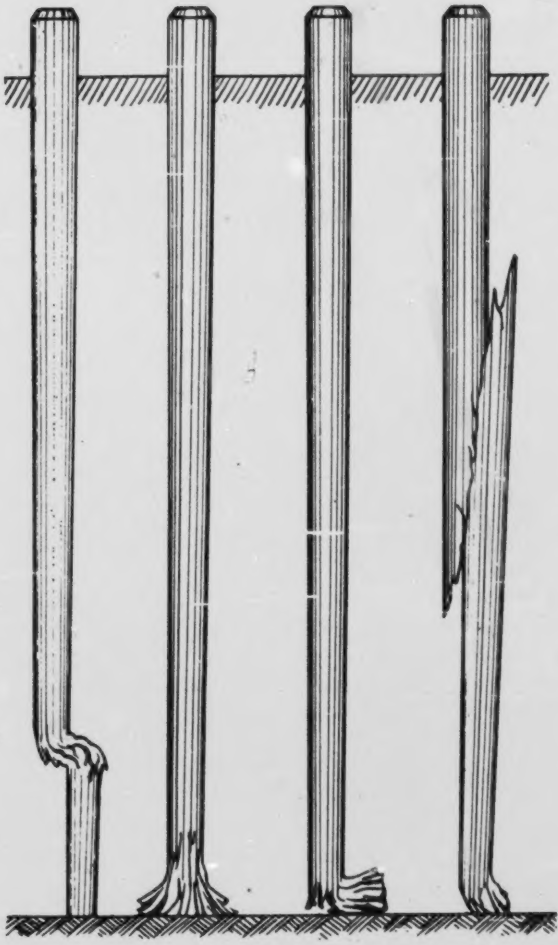


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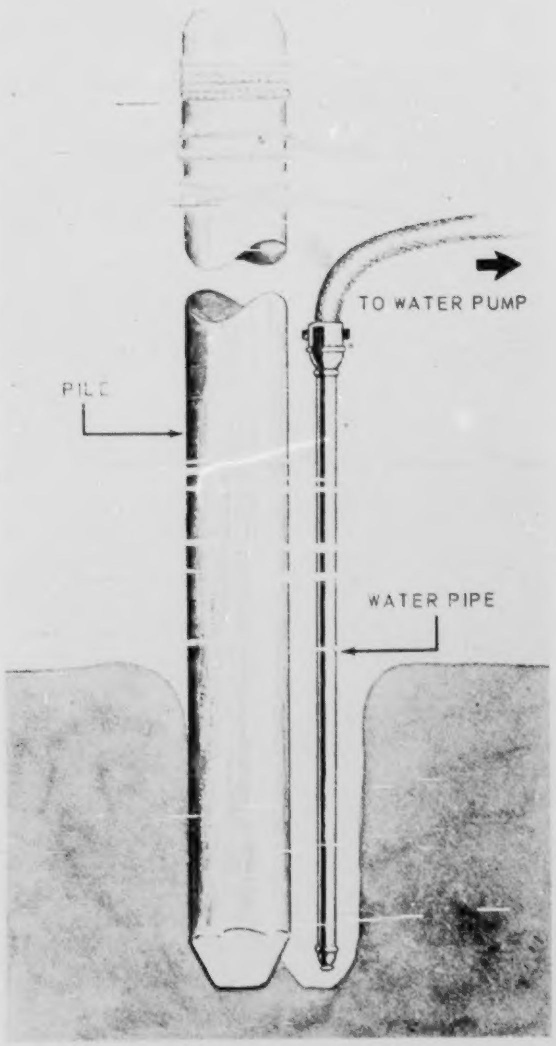
Figure 8-28. –Types of pile damage due to overdriving timber piles.



133.223

Figure 8-29. —Jetting with a single jet pipe.

Adequate precautions must include maintaining proper alignment of the pile during driving. In driving vertical piles using fixed leads, this is not often a matter of great concern, since the leads will hold the pile in correct alignment. If leads are used to drive batter piles, alignment of the leads should be checked occasionally. If difficulty is encountered in maintaining alignment, even if leads are used, the alignment should be checked by the use of transits, targets, plumb bobs, etc. When piles are driven with hanging leads, a flying hammer, or below the bottom of the pile leads, alignment of the pile must be watched carefully and checked frequently.

When piles are to be driven for a new foundation alongside an existing structure, care must be taken to ensure that the existing structure is not damaged by the operation. Shrinkage or heave of the ground around the new piles may seriously damage the foundations of an existing structure. If piles are to be driven behind a retaining wall, the pressure on the wall may be greatly increased; the increase in pressure may be caused by a consolidation of a granular soil by vibration, while a plastic soil may actually be forced against the wall.

Placing Piles By Jetting

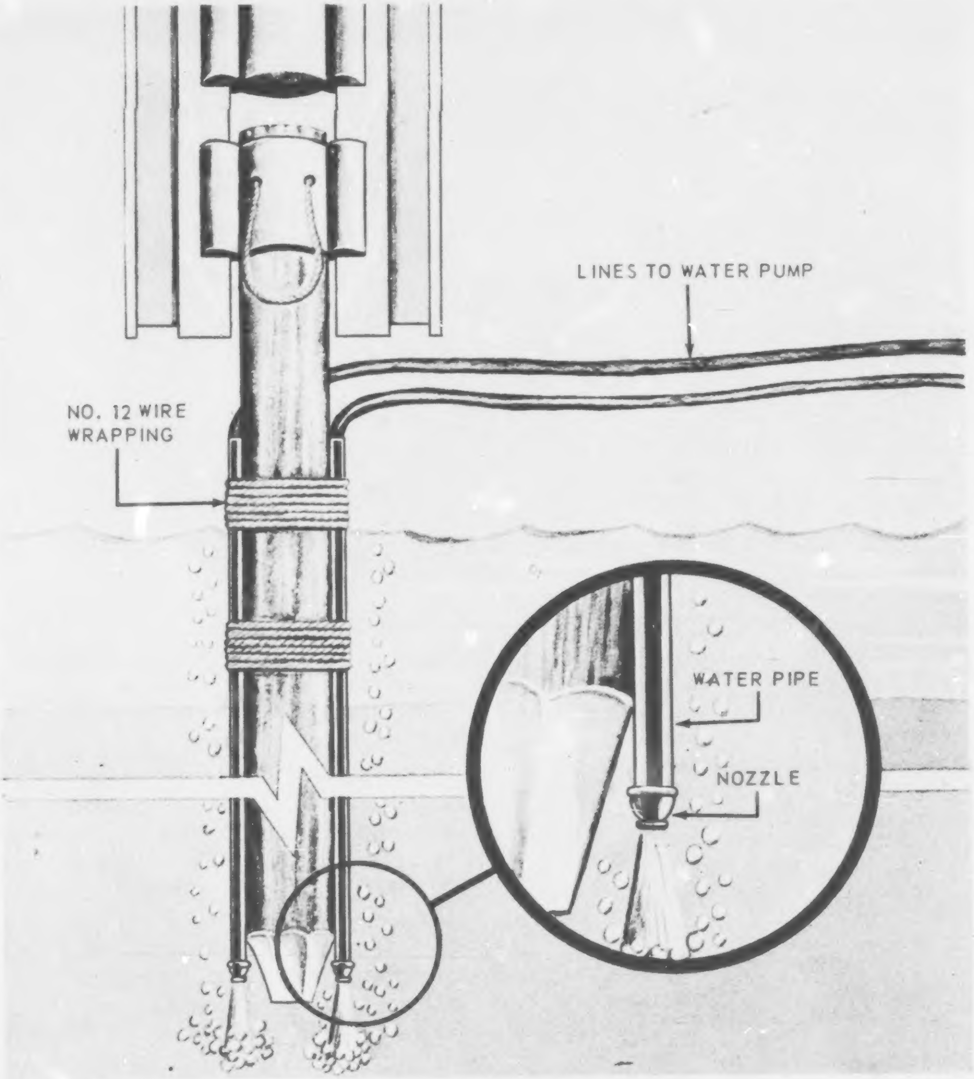
Pile penetration is often made easier by JETTING, or forcing water under pressure around and under the pile to lubricate and/or displace the surrounding soil as shown in figure 8-29. Jetting is not necessary or advisable in soils other than fairly coarse, dense sands. Jetting equipment consists of a water pump, a length of flexible hose, and a metal JET PIPE; jet pipes run from 2-1/2 to 3 inches in diameter.

A single jet pipe is used as follows. The pile is set in position, with the hammer resting on it for extra weight, and the jet pipe is manipulated to loosen and wash away the soil from under the tip as shown in figure 8-29. As the soil is washed away, the pile sinks under its own weight and that of the hammer. A few hammer blows are struck occasionally to keep the pile moving downward. When it is three feet above final tip elevation, the jet pipe is withdrawn and the pile is driven the rest of the way with the hammer.

The action of a single jet pipe on one side of a pile tends to send the pile out of plumb. Whenever possible, two pipes are used, lashed to the pile on opposite sides as shown in figure 8-30.

Extracting Piles

A pile which has met an obstruction, or which has split or broken in driving, or which is to be



133.224

Figure 8-30. —Jetting with two jet pipes.

salvaged (steel sheet piles are frequently salvaged for reuse) is usually PULLED (extracted). Pulling should be done as soon as possible after driving; the longer the pile stays in the soil, the more compact the soil becomes, and the greater the resistance to pulling will be. Methods of pulling piles are as follows.

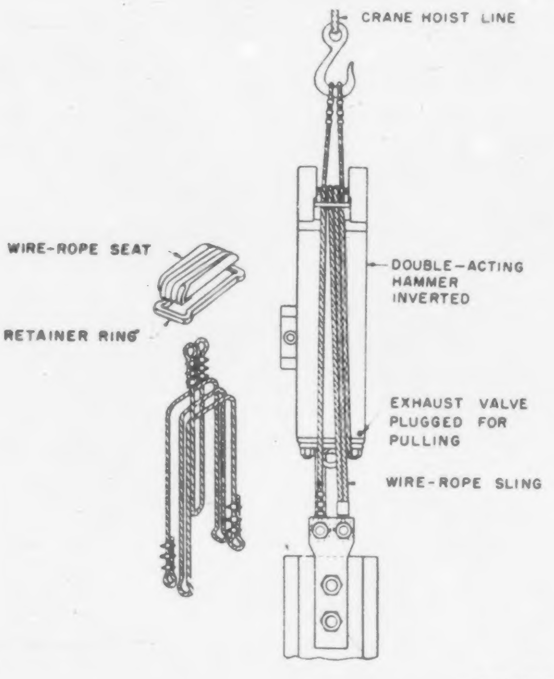
In the DIRECT LIFT method, a crane is used to pull the pile. The crane whip is slung to the pile and a gradually increased pull is applied, up to just a little less than the amount which is expected to start it. Lateral blows from a HEADACHE BALL (heavy steel ball, swung on a crane whip to demolish walls), or a few light blows on the butt or head with a driving hammer, are given to break the skin friction, and the crane pull is then increased to maximum capacity. If the pile still won't start, it may be loosened by jetting, or the lift of the crane may be supplemented by the use of hydraulic jacks.

The 5000-lb double-acting hammer may be used in inverted position to pull piles. The hammer is turned over and a wire rope sling is passed over it and attached to the pile (figure 8-31). The hammer whip is heaved taut, and the upward blows of the hammer ram on the sling, plus the pull of the hammer whip, are usually enough to pull the pile.

TIDAL LIFT is often used to pull piles driven in tidewater. Slings on the piles are attached to barges or pontoons at low tide; the rising tide pulls the piles as it lifts the barges or pontoons. To avoid the danger of tipping barges over, a barge should be placed on each side of the pile, with the lifting force transmitted by girders extending across the full width of both barges.

SAFETY DURING PILE DRIVING OPERATIONS

In directing pile driving operations, safety is your most important consideration. You can rely heavily on the Heavy Construction Technician (if one is assigned to your crew) for detailed technical knowledge of pile driving operations, but you will retain full responsibility for safety.


CRANE HOIST LINE
WIRE-ROPE SEAT
RETAINER RING
DOUBLE-ACTING HAMMER INVERTED
EXHAUST VALVE PLUGGED FOR PULLING
WIRE-ROPE SLING

117.414

Figure 8-31. —Wire-rope sling used with 5,000-pound air-steam hammer to pull piles.

Most of the safety considerations found in these operations are those common to all construction such as the safe use of tools and equipment. Most of your emphasis will be in ensuring that each member of your crew knows his assigned task and the manner in which each contributes to safe operations. A pile driving crew is usually made up of the following personnel:

Rig operator
Signalman
Loftman
Hoisting engineer
Hook on man
Valve operator (if an air or steam hammer is used)

The signalman is the boss of the rig and the only man who gives signals to the operator of the rig and valve operator. The only signal any other man may give that the operator will obey is the EMERGENCY STOP SIGNAL. "Loftman" is the man who works on the lead ladder. He guides the pile under the hammer and into the leads also unlocking the line from the pile. He also helps on the ground around the rig. "Hoisting engineer" is the man who runs the crane or the winches in lifting piles and the hammer. "Valve operator" is the man who operates the air or steam for the hammer. "Hook on man" is the man who hooks the line onto the piling to be driven. He also chamfers and points all the piling to be used and helps set the pile into the leads.

Standard pile driving safety precautions are as follows:

Men handling piles must wear heavy gloves, safety shoes, and protective hats.

Shin and foot guards must be worn by men who are working with adzes or who are heading or pointing piles with axes.

Men working with creosoted piles or timbers must wear goggles and apply protective cream to exposed skin areas.

Men working over the water must wear kapok safety vests or the equivalent, and each rig working over the water must be equipped with life preservers and life lines.

When a pile driver is not in use the hammer must be held in place at the bottom of the leads by a cleat or a timber fastened to the leads.

The main working platform on a pile driver must be kept clear of lumber, ropes, tools, debris, and all other unnecessary obstructions.

Great care must be exercised against bringing booms or leads into contact with any overhead high-tension wires.

A man must never place any part of his body under a suspended hammer unless the hammer is dogged or blocked in the leads.

PLANNING AND ESTIMATING PILE DRIVING OPERATIONS

If you possess a thorough understanding of the foregoing material on the principles of pile driving and the capabilities and limitations of pile driving equipment, preparing estimates of the manpower, man-days, and equipment required for a given project should present no real problem. Manpower estimates for bearing piles are based on a typical crew consisting of one crew leader, one crane operator, four men to place the piles in the leads, and one or two men to prepare the piles. This is based on the further assumption that the pile driver can pick up and place the piles in the leads. If he cannot, due to the location of the undriven piles, you must allow for an additional crane and increase the total man-days required by 15 percent. The time in man-days required to drive each pile depends on the type of pile and its length. Precast concrete bearing piles drive slower than wood or steel ones, and logically, the use of a longer pile usually means that you plan to drive it deeper, which will take more time. Under average conditions, it will take .08 man-days to drive a 25 foot wood pile, the same for a steel one, but 1.0 man-day for a precast concrete pile. This estimate takes into account pile preparation, placing it in the leads and driving, and cutoff, if required. Doubling the length will increase the time to .1 man-days for wood and steel piles and to 2 man-days for precast concrete piles. These estimates are for average working conditions; adverse conditions will increase the estimate by one-half and favorable conditions will decrease it to one-half the figures given.

When estimating the man-days required to complete a pile driving operation, don't forget to include time for the assembly of the leads and hammer, preparing the equipment for driving, cutting holes in steel piling to facilitate handling, and disassembly of the equipment upon completion, if required. You must also allow time for pile extraction if it is a required part of the project. The estimate per pile runs from 2.0 to .2 man-days for adverse to favorable conditions, with 1.1 man-days being the figure used for average conditions. This estimate is based on a typical crew consisting of one crew leader, one crane operator, and 2 to 4 additional men. Don't forget to add .4 man-days per pile for pile disposal if required.

The foregoing estimating procedures are those used for bearing piles where pile material and length were the variables. For estimating manpower and equipment requirements for driving sheet piles, the estimating depends on the pile material (wood, steel, or concrete) and the area of the pile to be driven. Table 8-1 lists the estimating factors to be used for sheet pile driving operations. Notice that the quick estimates for the three different types of sheet piles are all about equal.

COFFERDAMS AND CAISSONS

When a shaft for a foundation, or for some other construction purpose, must be excavated to a considerable depth, provision must be made for excluding soil and/or water from the excavation. Structures used for this purpose include cofferdams and caissons.

Cofferdams

Cofferdams are temporary structures enclosing an excavation, either on land or in the water, so that the work may be performed in the dry. If in water, they must be strong enough to resist hydrostatic head from maximum high water to the mud line and the lateral pressure of saturated soil from the mud line to the bottom of

Table 8-1. —Estimating for sheet piling

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Wood sheet piling:[1]				
Preparation	1000 SF	0.3	0.2	0.1
Place and drive	1000 SF	22.5	15.0	7.5
Bracing	1000 SF	13.5	9.0	4.5
Steel sheet piling:[2]				
Preparation	1000 SF	2.1	1.4	0.7
Place and drive	1000 SF	21	14	7
Bracing	1000 SF	9	6	3
Cut-off (permanent piling only)	1000 SF	1.5	1.0	0.5
Concrete sheet piling:[2]				
Place and drive	1000 SF	25.0	17.0	8.5
Bracing	1000 SF	10.5	7.0	3.5
Cut-off (when required)	1000 SF	15	10	5
For quick estimates:				
Wood sheet piling, complete	1000 SF	36	24	12
Steel sheet piling, complete (no cut-off)	1000 SF	33	21	11
Concrete sheet piling, complete (no cut-off)	1000 SF	36	24	12
Install deadman and tieback	Each	18	12	6

Typical crew: Wood sheet piling: 1 crew leader, 1 man with power hammer, 4 men on pile preparation and bracing.

Typical crew: Steel and concrete sheet piling: 1 crew leader, 1 pile driver operator, 4 to 6 men on pile preparation, driving and bracing.

[1] Based on average depth of 20 feet

[2] Based on average depth of 30 feet

117.415

the excavation. If on land, they must resist the lateral pressure of dry earth above the ground water line and of saturated earth below it. They must be substantially watertight and must penetrate far enough below the bottom of the excavation to afford an adequate cutoff to minimize seepage, blowouts, and boils through the bottom of the excavation.

The simplest form of cofferdam is the EARTH COFFERDAM which is built by constructing an earthfill, shaped so that it will surround the construction area without encroaching upon it. It is effective only if the bottom is impermeable or, if permeable, is of such character that the inflow of water can be controlled readily by pumping or well pointing. Because swiftly moving currents would carry the fill material away, the use of earth cofferdams is limited to relatively quiet and shallow waterways where the velocities do not exceed 5 ft per second. The more commonly used cofferdams are the internally braced types which include those made from various combinations of sheeting, lagging, and piling.

Many braced cofferdams have been built of WOOD SHEET PILING. The sheet piling may be of large-dimension timber with tongues and grooves, heavy timber planking, or may be of several thicknesses of thinner lumber with staggered joints, known as Wakefield sheet piling. Horizontal wales of timber or steel are placed inside the sheeting and braced by struts transversely across the excavation. Successive tiers of wales and struts are placed progressively, generally at decreasing intervals, as the excavation is deepened and dewatered. Each end of the cofferdam is similarly braced by longitudinal struts, or, in a long cofferdam, by diagonal struts carried back and supported from the longitudinal wales. In some cases, trussed bracing is used to leave the central portion of the cofferdam unencumbered by bracing.

Braced cofferdams of STEEL SHEET PILING are like those of wood sheet piling except that interlocking steel sheet piling is used for the exterior walls. Wales are generally of structural steel members. Bracing may be either steel shapes, timbers, or built-up box sections of steel or wood. Figure 8-32 shows a cofferdam under construction.

For cofferdams on land, master piles of structural shapes are sometimes driven at regular spacing and the spaces between them protected by horizontal planks held against the flanges of the master piles as shown in figure 8-33. As excavation proceeds, the planks are inserted progressively from the top down and generally have beveled edges. Bracing is placed opposite the master piles, and horizontal wales are omitted.

CAISSONS

Caissons are permanent structures, intended to carry the loads of massive buildings and bridge structures down to bedrock. They may vary from very small cylinders to extremely large rectangular or cylindrical shapes. Caissons, which are merely casings or shells, are classified

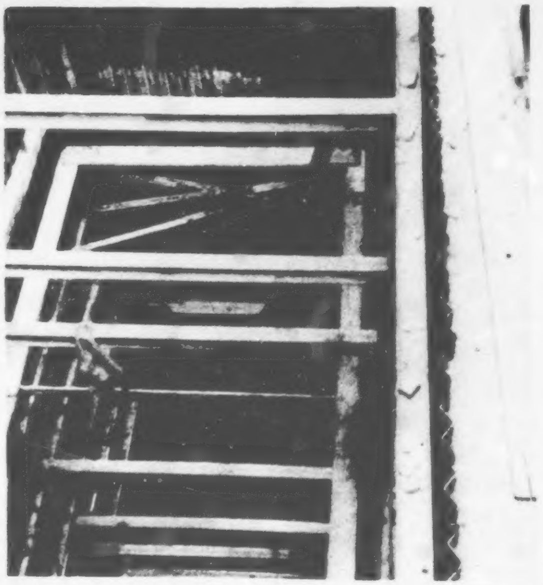


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Figure 8-32. –Steel sheet piling cofferdam.

according to their make and usage. An OPEN caisson is open at both top and bottom. A BOX caisson is open at the top but closed at the bottom. If the caisson is open at the bottom and closed at the top, it will require compressed air to carry on the excavation work inside, and is then known as a PNEUMATIC caisson. The most frequently used caissons are the box and open caissons.

Box Caissons

A box caisson is a hollow structure with exterior walls and a solid floor, but with no top. It may have internal walls, struts, or diaphragms and may be of timber, steel or concrete. Box caissons usually are restricted to use for the underwater portion of bridge piers or harbor protection structures. They are frequently built ashore, launched, towed to the site, sunk in position in an excavated hole, and then filled with stone, concrete, or sand as required. Figure 8-34 shows a concrete box caisson as used in the construction of a caisson breakwater/jetty. Note that the caisson was filled with sand and capped with concrete.

Open Caissons

Open caissons differ from box caissons in that no floor is provided. They are used extensively *for deep foundations* and bridge pier substructures. They may be of wood, steel, or concrete and are provided with cutting edges to facilitate sinking. Open caissons are usually sunk by excavating the material from within the caisson and allowing the caisson to sink into the excavation. Excavating can be done by hand or machine. Drilling rigs equipped with auger bits or orange peel-type buckets, and cranes equipped with clam-shell buckets are examples of the types of machines used in excavating for caissons. Sinking is facilitated by building up the walls of the caisson as it sinks, thereby adding to its weight; by adding supplementary weights; by jetting outside the caisson walls; and by driving with a pile hammer. This latter procedure is applicable only to steel tubular caissons reinforced at the top and thick enough to stand driving. One hammer, acting on a beam across the top of the caisson, may be sufficient; or two hammers, acting simultaneously but not necessarily synchronized, may be required depending on caisson size.

After the caisson is sunk to final grade and position, the bottom is sealed and/or belled out depending on the character of the foundation

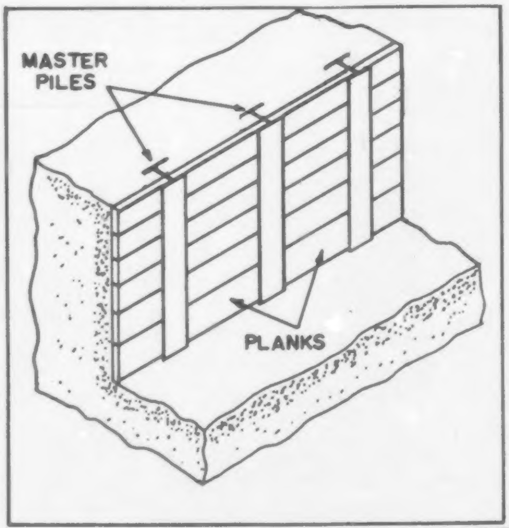

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Figure 8-33. –Portion of cofferdam wall.

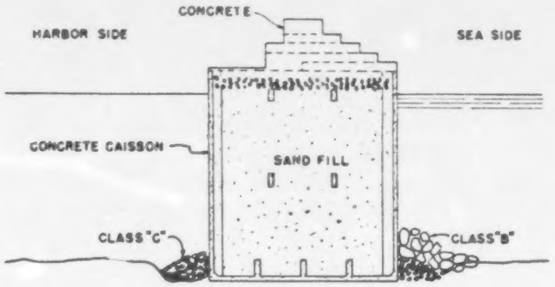

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Figure 8-34. —Caisson breakwater/jetty.

stratum. If the caisson is to be founded on firm clay or hardpan, the caisson is carried down far enough into the material to form a seal and any water present is pumped out. Bells for enlarged bearing capacity are formed by excavating in the dry, using hand methods. If clay or hardpan lies immediately above rock which is to be used as a foundation bed, the seal is established and excavation is carried on through these materials to rock, using the procedures just given, the clay walls being supported by sheeting or by whatever is necessary. Usually no support is required in hardpan, and often none is required in clay. If the porous water-bearing soil continues until rock is reached, the caisson is carried to the rock and a concrete seal is established between the bottom of the caisson and the rock. You may sometimes hear this seal referred to as a tremie seal, the reason being that when concrete is placed in the bottom of a caisson through water, the concrete is placed using a tremie. After the tremie seal has set, the water is pumped out and the rest of the caisson is filled with concrete in the dry.

SHORING

One of the inherently hazardous parts of construction operations is that of excavating. The principal hazards of excavation work are:

1. Collapse or failure of excavation walls burying workers and equipment;
2. Materials, tools, equipment falling into holes and striking workers below;
3. Hazards involving public utilities, such as electricity, water, gas or natural gases and oxygen deficient atmosphere;
4. Wet muddy conditions, causing slips, trips or falls complicated by limited spaces in which to work.

SHORING LARGE EXCAVATIONS

Figure 8-35 shows a picture of a very deep and very large excavation. Notice that the wall has collapsed because it was not shored and is much too high and steep to be stable under all conditions. Contributing to the cave-in was the superimposed load caused by the crane just on the edge of the excavation. Superimposed loads on the ground surface next to excavations, including the spoil from the hole itself, can place enough stress on the soil to cause failure. Shock and vibration from such things as pile driving, blasting, traffic passing by, or vibration-producing machinery can also cause a cave-in. Water pressure from ground water flow can loosen the soil and reduce its cohesiveness. Excessive moisture from rain or snow can reduce the tendency of the soil to stick together and cause failure. Even excessive drying of the soil can cause a slide or collapse.

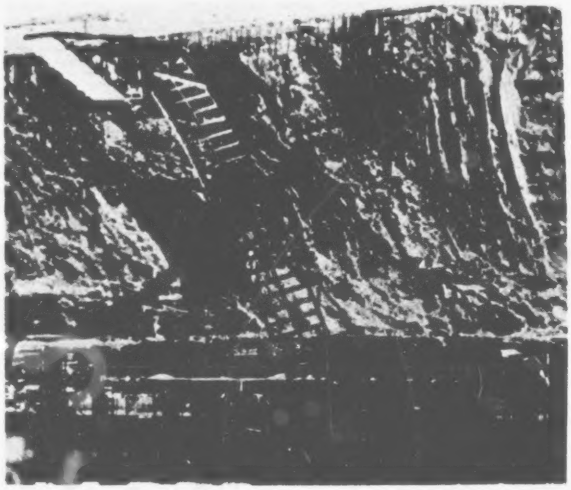

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Figure 8-35. —Large excavation.

The important thing to remember is that excavation walls or trench walls change conditions, depending on moisture, drying, and load so that what may be safe at one time is not safe at another, and these changes occur often without sufficient warning to protect workers. The solution to side wall collapse is, of course, shoring and bracing walls of major excavations. Shoring large excavations involves much the same type of operations as were involved in the construction of cofferdams discussed earlier. Because of the complexity of the various types of pressures encountered in shoring and bracing large excavations, the structural design (to include the methods and materials) should be determined by a qualified engineer. No attempt is made here to acquaint you with such engineering information as it is beyond the scope of this manual. Some of the shoring methods used include:

1. Driving vertical wood or steel sheeting around the sides of the area to be excavated; and re-driving the sheeting as excavation progresses. (See figure 8-36.)

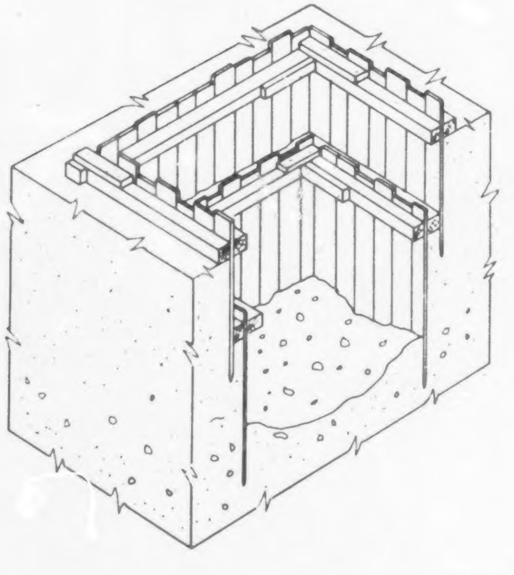

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Figure 8-36. —Shoring an excavation with wood sheet piling.

2. Installing sheeting boards around the sides of the excavation as it progresses downward. (See figure 8-37.)

3. Driving soldier beams and placing sheeting boards between them as the excavation progresses. (See figure 8-38.)

SUPPORT FOR ADJACENT STRUCTURES

In many instances, it is necessary to carry the excavation for a new building right up to the foundation of an existing one. This presents a problem if the new excavation is to be deeper than the footings of the existing building. Part of the support for those footings will be removed, and it is the responsibility of the Builder to protect the building against movement caused by settlement during and after construction of the new building. Temporary support may be provided by shoring or needling, while permanent support is provided by underpinning–extending the old foundation to the level of the new one.

A common method of providing support is by the use of up to 12 x 12 timbers called SHORES, inclined against the wall to be supported and extending across the excavation to a temporary FOOTING consisting of a framework

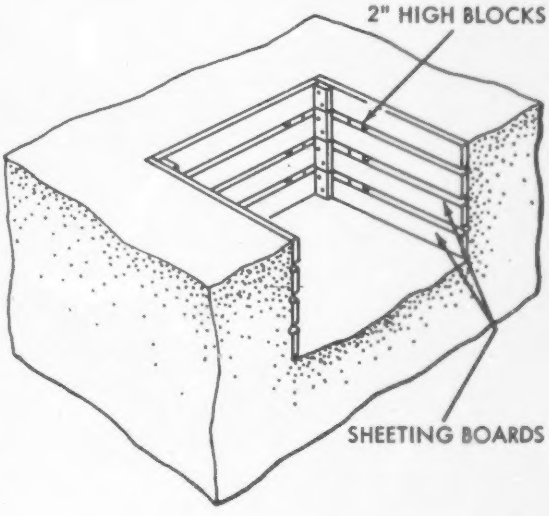

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Figure 8-37. – Shoring with sheeting boards.

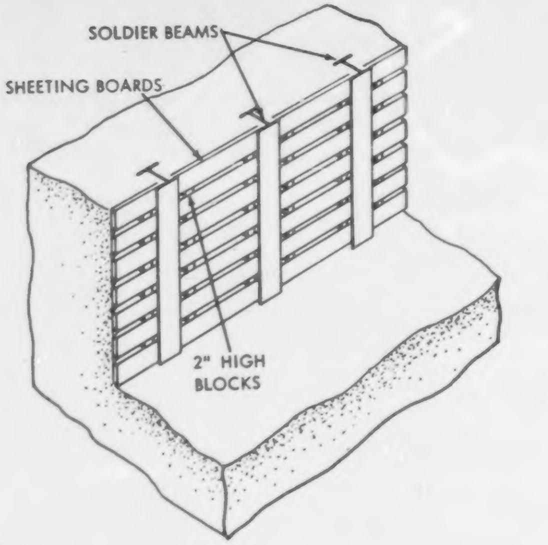

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Figure 8-38. —Soldier beams and sheeting.

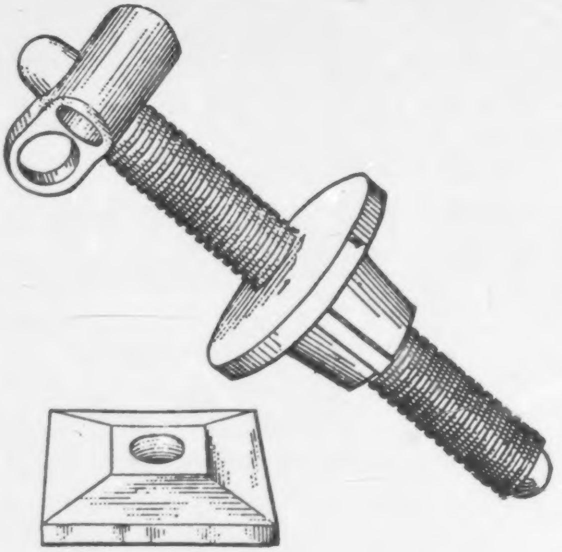

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Figure 8-39. —Standard steel screw jack.

or mat of timbers laid on the ground. The upper ends of the shores may be fitted into openings cut in the wall, or they may butt against a timber bolted to the wall. Steel SADDLES may be placed in openings cut in concrete or masonry walls to support lifting or steadying shores.

It is good practice to set shores as nearly vertical as possible, to reduce lateral thrust against the wall. Heads of shores should, whenever possible, be located at floor levels, to minimize the danger of pushing the wall in.

Provision for inducing a lift or thrust in the shores is usually made by inserting jacks between the bases of the shores and the footing. Figure 8-39 shows a standard steel SCREW JACK. One of these may apply a lift of as much as 100 tons. When a single screw jack is used with a shore, a hole is bored in the base of the shore to admit the threaded portion of the jack, and the arrangement is called a PUMP. For a larger lifting effect, a pair of jacks are attached to a short timber called a CROSSHEAD. Pump and crosshead arrangements are illustrated in figure 8-40.

An advantage of the crosshead arrangement is that after a lift has been applied, the crosshead can be blocked and the jacks removed for use elsewhere.

HYDRAULIC jacks provide a much stronger lift than screw jacks, but cannot be used to support a load over a length of time. However, with a pair of hydraulic jacks in crosshead arrangement, as many shores as desired can be

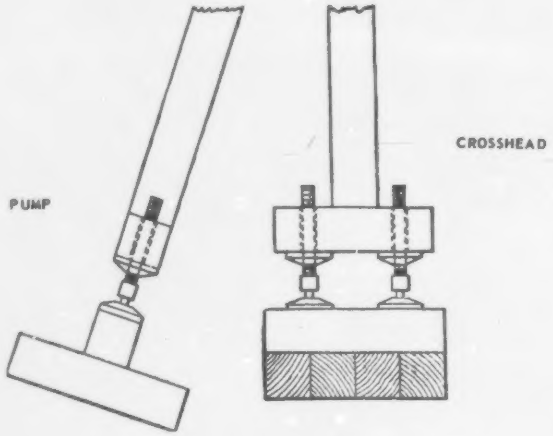

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Figure 8-40. —Pump and crosshead.

set up and blocked in a short time and with a minimum of labor.

Figure 8-41 shows a project which involves a construction procedure known as UNDERPINNING. The feature marked W is a wall, resting on a footing, BB. Excavation is to be carried down to the level indicated by the horizontal dotted line, which means that the earth supporting the footing BB is to be completely removed. The existing wall is to be supported during this procedure, and subsequently a new foundation wall extended upward from the footing shown below. This is the process known as underpinning.

Support for the wall will be provided by a series of NEEDLES, that is, of heavy timbers or steel beams, inserted horizontally through holes cut in the wall, and wedged or jacked upward so as to assume the weight of the wall. In figure 8-41 the member marked GG is a needle. The needling and underpinning procedure shown in that figure would be carried out about as follows.

Before actual underpinning operations are begun, complete preliminary investigations are made, especially with regard to soil bearing capacity. Too much emphasis cannot be placed upon this point. The neglect of adequate study and proper interpretation generally proves very costly. Soil samples should be properly taken, and the results interpreted by trained engineers. The depth and character of the soil should be determined, and it should be ascertained that a suitable stratum is not underlain by softer material.

After the preliminary investigations have been made, a pit, DDDD, is excavated down to the level of the top of the proposed new footing. At the bottom of this pit a layer of heavy timbers, FF, is laid on a layer of thick planks. At grade level on the other side of the wall a similar platform is laid. Holes are cut in the wall and the needles are inserted, each supported at the pit end by vertical timber and blocks, MN, and at the other end by a screw jack. The lift at the pit end is obtained by driving wedges at K, at the other end by the jack.

Before the material under the wall is excavated, sheet piles are driven at LL. As excavation proceeds downward, these are shored up as shown, to prevent a slide caused by the weight of the nearby grade-level platform.

Obviously, only that portion of the wall which is directly above a needle will receive direct support from the needle. Other portions of the wall above the needles will receive

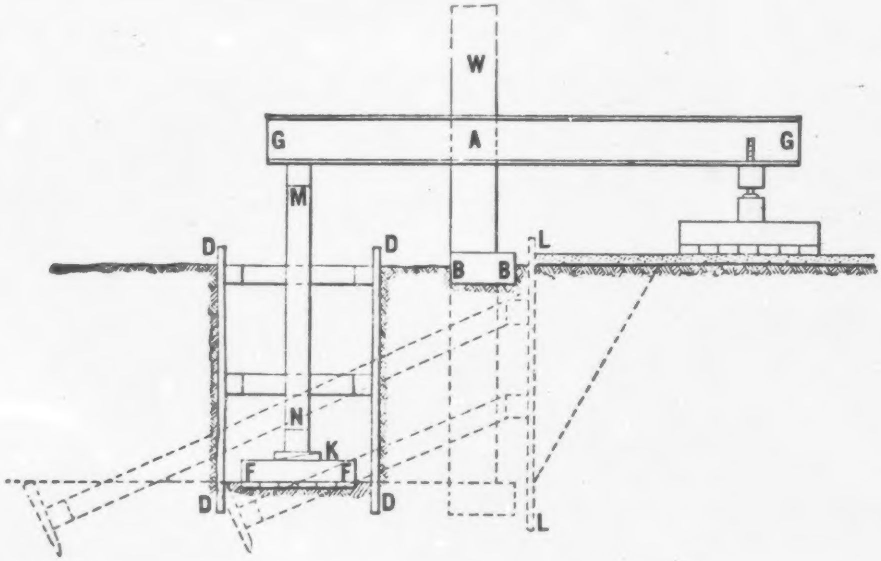

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Figure 8-41. —Needling and underpinning.

indirect support by oblique transfer of the needles' upward thrust through the material; however, some parts of the wall above the needles will receive no support at all. Consider, for example, the section of needled brick wall shown in figure 8-42. The oblique corbel outward of the upward thrust of the needles through the material is indicated by the line, AAAAA. Only the portion of the wall above this line is receiving support from the needles. All of the wall below this line will be hanging when the support under the footing is removed. The hanging part will be held up to some extent by cohesion to the supported part, but it is important for you to know that this is all the support it will have. In a brick wall, of course, cohesion of this type would be slight; in a reinforced concrete wall it would be much greater. Sometimes the hanging part of a needled wall is preserved by chaining or wiring it firmly up to the supported part.

When the new footing has been constructed and the new wall carried up to the old wall, joining the wall sections in a manner which will allow a transfer of the weight of the supported wall from the needles to the new wall without settlement presents a problem. In the case of a brick wall, WEDGING STONES may be inserted in the new wall, at needle level, as shown in figure 8-43. As the last course of brick between the old wall and the new is laid, the joint is compacted as tightly as possible by driving pieces of slate into the mortar, and steel wedges are driven home between the wedging stones, to transfer most of the weight of the wall to the new underpinning. The jack is then backed off to release the needle, and the needle is removed.

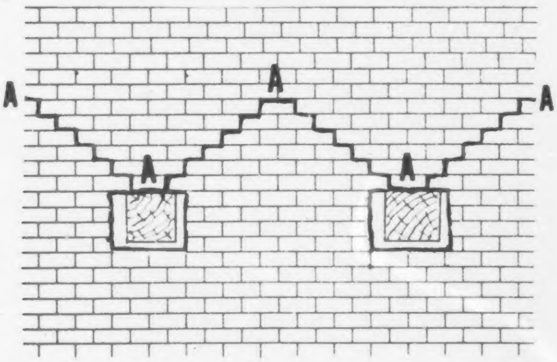

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Figure 8-42. —Line of demarcation between supporting and hanging brick wall in underpinning.

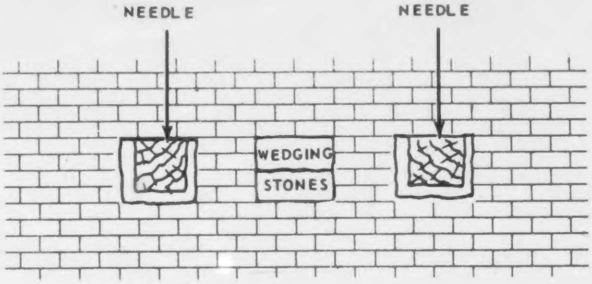

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Figure 8-43. —Wedging stones.

In the method of needling just described the needle is used as a beam—meaning that it is supported at both ends and sustains a downward load in the middle. Figure 8-44 shows a situation in which this method of needling is not feasible, probably because the erection of a supporting platform for the inner end of the needle inside the building is not feasible. In this case the FIGURE-4 method of needling is being used, with the needle serving as a CANTILEVER rather than as a beam.

EXCAVATION SAFETY

Burial alive in an excavation slide or cave-in is a terrible accident which occurs in the construction industry with scandalous frequency. Application of the basic excavation safety rule—that any excavation 4 ft or more in depth must be protected by one of the prescribed methods—would reduce this frequency almost to nil. There are additional safety rules, most of which have the same basic purpose; that is, to prevent slides or cave-ins. Some of these rules are as follows:

Any trees, boulders, or other surface encumbrances located close enough to create a hazard must be removed before excavation begins.

If it is necessary to bring power shovels, derricks, trucks, large quantities of supplies, or

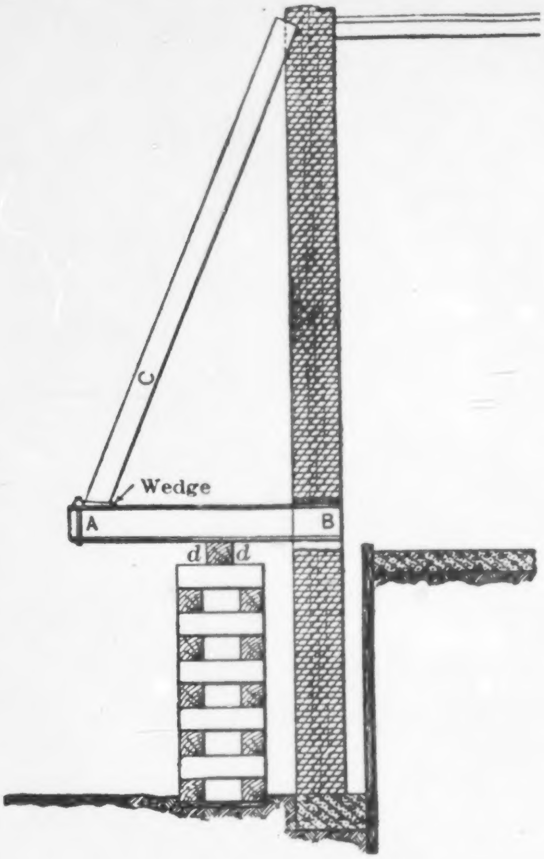

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Figure 8-44. —Figure-4 method of needling.

other heavy objects or materials near an excavation, the face of the excavation which is toward the object or material must be ADDITIONALLY shored and braced to resist the additional pressure. NO object or material should be placed within 2 ft of the edge of an excavation.

When soil against the face of a masonry wall is excavated, it must not be presumed that the wall will, of itself, provide sufficient support against lateral pressure from unexcavated material on the other face. The wall must be adequately shored and braced.

Temporary sheet piling installed to permit construction of a retaining wall must not be removed until the wall has developed full strength–meaning, for a concrete wall, usually 28 days.

Undercutting of earth banks should be done only when it is unavoidable, and then only as the overhang is kept progressively and adequately shored and braced.

Excavations must be inspected after every rainstorm or similar hazard-increasing occurrence, and the protection against slide or cave-in increased if necessary.

No sidewalk may be undermined without being progressively shored to carry a live load of 125 psf. Excavated material must not be piled on sidewalks or walkways.

All timber used for shoring, bracing, sheathing, and sheet piling must be sound, straight-grained timber, of strength and quality equal to that of long-leaf yellow pine or Douglas fir, and free from splits, shakes, large or loose knots, or other strength-impairing defects.

Wooden sheet piling must not be less than 2 in. thick for a depth of up to 16 ft, not less than 3 in. for a depth of up to 24 ft, and not less than 4 in. for a depth of up to 40 ft.

If pedestrian and/or vehicular traffic must be maintained over or near excavations, all proper safeguards, such as bridges, walkways, guardrails, barricades, warning flags, and lights, must be installed.

Entrance to and exit from any excavation over 5 ft deep must be by properly constructed ramp, ladder, stairway, or hoist. Jumping into trenches and the use of bracing and shoring members for climbing must be prohibited.

Tools, materials, and debris must not be left on bridges or walkways over excavations, on shoring and bracing members, near the edges of excavations, or in any other position from which they might fall on men in the excavation below.

Pick and shovel men working in excavations must keep far enough apart to avoid striking each other accidentally with tools.

HARBOR PROTECTION STRUCTURES

Harbor protection structures may be broadly divided into two categories, as follows: (1) OFF-SHORE STRUCTURES like breakwaters and jetties, designed and constructed so as to create a sheltered harbor, and (2) ALONGSHORE STRUCTURES like seawalls and bulkheads, designed and constructed to establish and maintain a stable shore line.

BREAKWATERS AND JETTIES

A BREAKWATER is an off-shore barrier placed at the outer limits of a harbor and erected so as to "break" the action of the waves of the open sea and thereby create an area of calm water inside the breakwater. A JETTY is a structure placed at or near the entrance of a harbor or river and erected so as to confine the flow of water, due to currents and tides, and maintain the entrance channel in position. Breakwaters and jetties are alike in construction; the chief distinction between them lies in the above mentioned difference in purpose.

The simplest type of breakwater/jetty is the RUBBLE-MOUND (also called ROCK-MOUND) type shown in figure 8-45. Rock for a structure of this type is classified according to size as follows:

CAP ROCK: the largest rocks available, approximately rectangular in cross-section, with the smaller cross-section dimension not less than 1/3 of the larger.

CLASS A ROCK; not less than 85 percent consisting of rocks weighing more than 2 tons each.

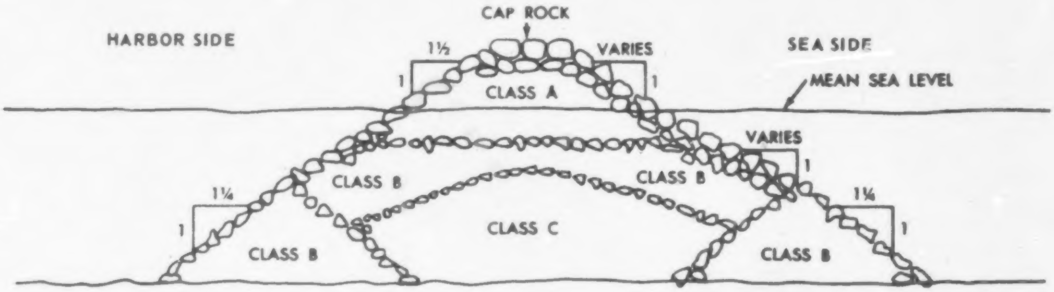
CLASS B ROCK: not less than 60 percent consisting of rocks weighing more than 100 lbs each.

CLASS C ROCK: rock smaller than class B, technically known as QUARRY WASTE.

In designing a rubble mound breakwater/jetty the width of the CAP is first decided upon; this width may vary from 15 or 20 ft up to as much as 70 ft. The width of the base will depend upon the width of the cap, the height of the structure, and the specified slopes of the inner and outer FACES.

Rubble mound breakwaters and jetties are constructed by dumping underwater rock from scows, or from rail cars running on temporary pile-bent structures, and by placing upper rock and cap rock with floating cranes. As indicated in figure 8-45, the first rock placed usually consists of marginal mounds of Class B, extending up to about 20 ft below mean sea level. A CORE of Class C rock is then dumped between the marginal mounds, also extending up to about 20 ft below mean sea level. A layer of Class B rock is then placed as shown; this layer is usually brought up to the EXPECTED MAXIMUM WAVE HEIGHT below MEAN LOW WATER. The level of mean low water is shown on the CHART of the area. (Mean low water is the average sea level at low tide.) The rest of the breakwater is then built up of Class A rock and cap rock, as shown.

For a deep-water site, or for one with an extra-high range between high and low tide, a rubble mound breakwater-jetty may be topped with a CAP STRUCTURE to form the COMPOSITE type of breakwater/jetty shown in figure 8-46. The cap structure in this case consists of a series of precast concrete boxes called concrete CAISSONS, each of which is



45.527

Figure 8-45. —Rubble mound breakwater/jetty

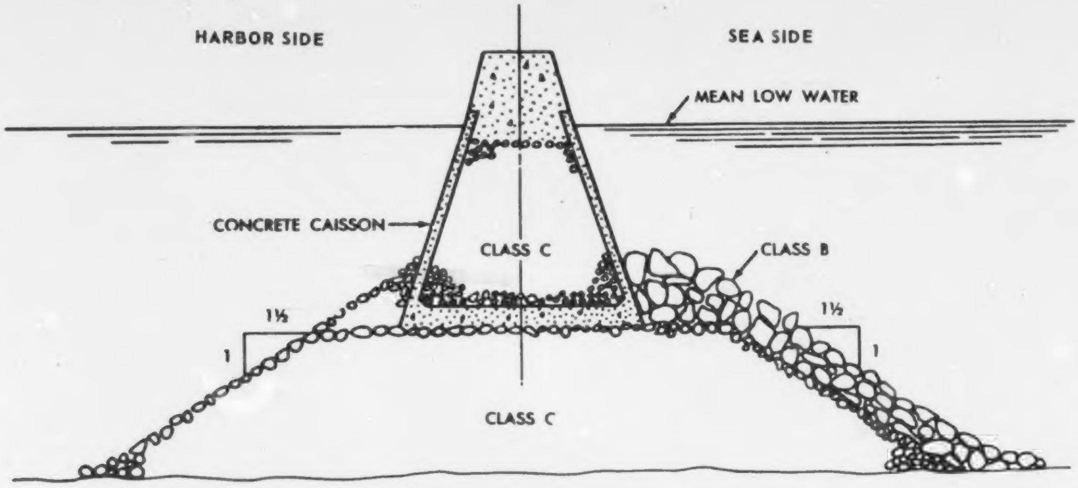


Figure 8-46. –Composite breakwater/jetty.

floated over its final location and sunk into place by filling with Class C rock. A monolithic (single-piece) concrete cap is then cast in place on the tops of the caissons.

SEAWALLS

Seawalls vary widely in details of design and materials, depending on the severity of the exposure, the value of the property to be protected, and other considerations. Basically they consist of some form of barrier designed to break up or reflect the waves and a deep, tight cutoff wall to preclude washing out of the sand or soil behind and under the barrier. The cutoff wall is generally of timber, steel, or concrete sheet piling. Figure 8-47 shows a rubble stone sea wall, built much like a rubble mound breakwater. Stone which is used to protect a shore line against erosion, however, is called RIPRAP, and a rubble stone sea wall is therefore called a RIPRAP sea wall.

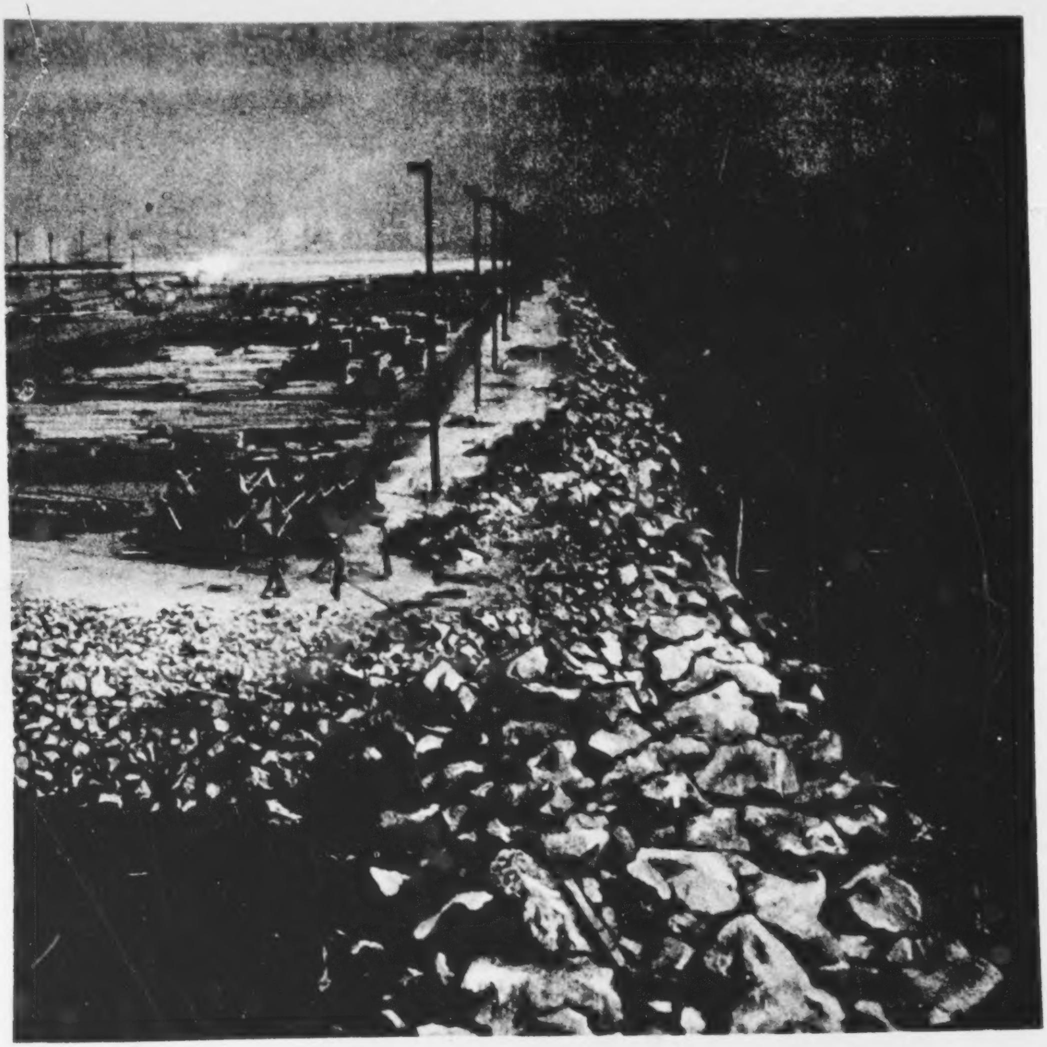
Various types of cast-in-place concrete sea walls are the VERTICAL-FACE, the INCLINED-FACE, the CURVED-FACE, the STEPPED-FACE, and the COMBINATION CURVED-FACE and STEPPED-FACE. Note, the sea or harbor bottom along the TOE (bottom of the outside face) of a sea wall is usually protected against erosion (caused by the backpull of receding waves) by riprap piled against the toe.

BULKHEADS

A BULKHEAD is used for the same general purpose as a sea wall, namely, to establish and maintain a stable shore line. The chief distinction between the two is that a sea wall is a self-contained, relatively thick wall which is supported by its own weight, while a bulkhead is a relatively thin wall which is supported by a series of TIE WIRES or TIE RODS, running back to a buried ANCHORAGE. A timber bulkhead for a bridge abutment is shown is figure 8-48.

The bulkhead shown in figure 8-48 is made of wood SHEATHING (square edged, single-layer planks), laid horizontally. Most bulkheads, however, are made of sheet piles, and of the three types of sheet piles (wood, steel, and concrete), steel sheet piles are by far the most frequently used. Figure 8-49 shows a constructed steel sheet pile bulkhead.

The outer ends of the tie rods are anchored to a steel WALE which runs horizontally along the outer face of the bulkhead. This wale is usually made up of pairs of steel CHANNELS bolted

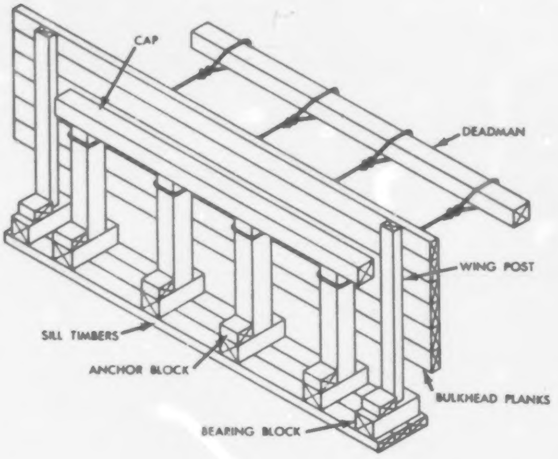


133.229

Figure 8-47. —Riprap sea wall.

together back-to-back. (A channel is a structural steel member with a U-shaped section.) Sometimes the wale is placed on the inner face of the bulkhead and the piles are bolted to it.

In figure 8-49 the anchorage in the figure is covered by backfill. In stable soil above the ground water level the anchorage may consist simply of a buried timber or concrete deadman or a row of driven and buried sheet piles. A more substantial anchorage for each tie rod must be used below the ground water level. Two commonly used types of anchorage are shown in figure 8-50. In figure 8-50(A) the anchorage for each tie rod consists of a timber CAP, supported by a batter pile which is bolted to a bearing pile. In figure 8-50(B) the anchorage consists of a reinforced concrete cap, supported by a pair of batter piles. As indicated in the figure, tie rods are supported by supporting piles located midway between the anchorage and the bulkhead.



133.230

Figure 8-48. –Timber bulkhead for bridge abutment.

Bulkheads are constructed from working drawings like those shown in figure 8-51. As indicated in the plan, the anchorage for this bulkhead consists of a row of sheet piles, to which the inner ends of the tie rods are anchored by means of a channel wale.

The order of construction sequences is indicated in the section. The shore and bottom are first excavated to the level of the long, sloping dotted line. The sheet piles for the bulkhead and the anchorage are then driven. The supporting piles for the tie rods are driven next, after which the tie rods between the bulkhead and the anchorage are set in place and the wales are bolted on. The tie rods are prestressed lightly and uniformly, and the backfilling then begins.

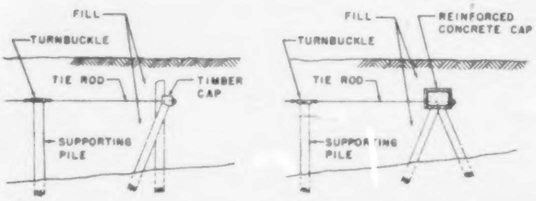
The first backfilling operation consists of placing fill over the anchorage, out to the dotted line shown in the plan. The turnbuckles on the tie rods are then set to bring the bulkhead plumb, and the rest of the backfill is worked out to the bulkhead. After the backfilling is completed, the bottom outside the bulkhead is dredged to the desired depth–in this case, 30 ft.

TRANSPORTABLE SAWMILL

In previous sections of this chapter, mention was made as to the use of wood in various types of construction operations involving pile driving and shoring. The transportable sawmill presently available to a SEABEE unit, as augmented equipment, enables the unit to produce lumber for such purposes, regardless of location, as long as timber is available. The transportable sawmill currently in use is the MIGHTY MITE, Model

133.231

Figure 8-49. –Constructed steel sheet pile bulkhead.



Ⓐ BATTER PILE ANCHORAGE WITH TIMBER CAP

Ⓑ A-FRAME PILE ANCHORAGE WITH REINFORCED CONCRETE CAP

133.232

Figure 8-50. –Two types of tie rod anchorages for bulkheads.

G-812-H. The Mighty Mite is a lightweight, portable, two-man precision sawmill that operates on the unique principle of moving saws along a log instead of moving logs through saws.

COMPONENTS

The basic mill consists of a series of components which include (1) engine and frame assembly shown in figure 8-52, (2) the saw frame assembly shown in figure 8-53, (3) the end stands assembly (two required) shown in figure 8-54, and (4) the heavy duty track assembly shown in figure 8-55. The line drawing in figure 8-56 shows the basic mill set up and the use of mud mills for stability. For complete assembly instructions as well as maintenance requirements, users should consult the Owner's Book provided by the manufacturer.

CAPABILITIES

When assembled, the mill can cut logs up to 6 ft in diameter and 18 ft 6 inches in length into dimension lumber as small as 1 x 2 inches and as large as 8-1/4 x 12-1/2 inches. Smaller logs can be piled into a pyramid arrangement or stacked and chocked into multiple log decks as long as the width of the stack does not exceed 6 ft in height and 7 ft in width.

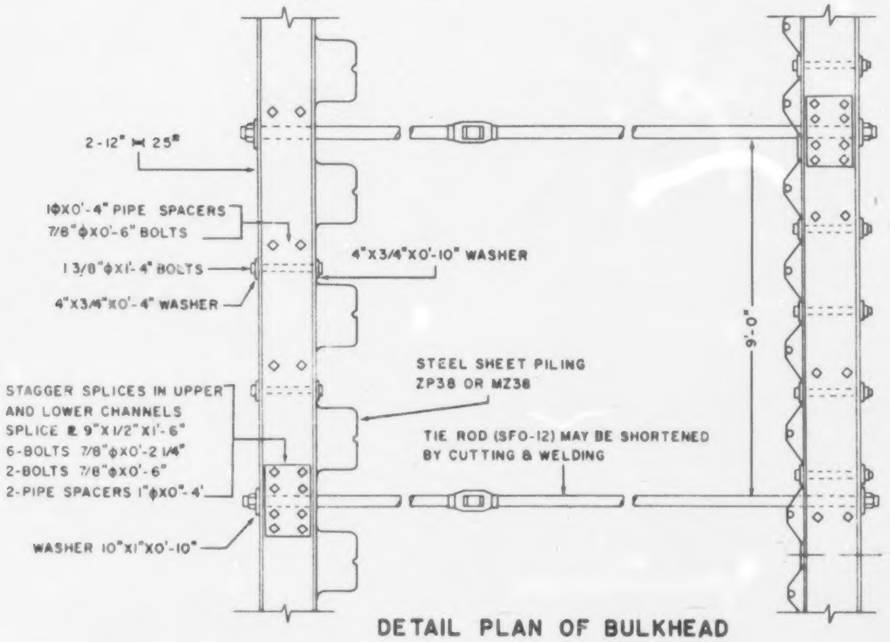
CREW AND SUPPORT EQUIPMENT REQUIREMENTS

The Mighty Mite can be assembled anywhere on fairly level ground by two men in approximately 2 hours. Under normal conditions, optimum efficiency can be maintained with a two man team. One man operates the saw while the other offbears the cut lumber. Dimension lumber up to 2 x 12 inches may be handled off the mill by hand. When cutting heavy species of dimension lumber, the scissors type offbearing table (figure 8-57), available as an accessory, should be used for safety and maximum production. The table is hydraulically adjustable for height, includes sectionalized rolls and gravity rolls for side discharge. When available, a crane equipped with a boom and jib can be used to offbear cut lumber and also to position logs, thereby increasing safety and production. Additional equipment and personnel may be required to assist the two man team in positioning logs for cutting depending on their size, location, and the production desired. If additional personnel and equipment are not available, the mill can always be moved to the log.

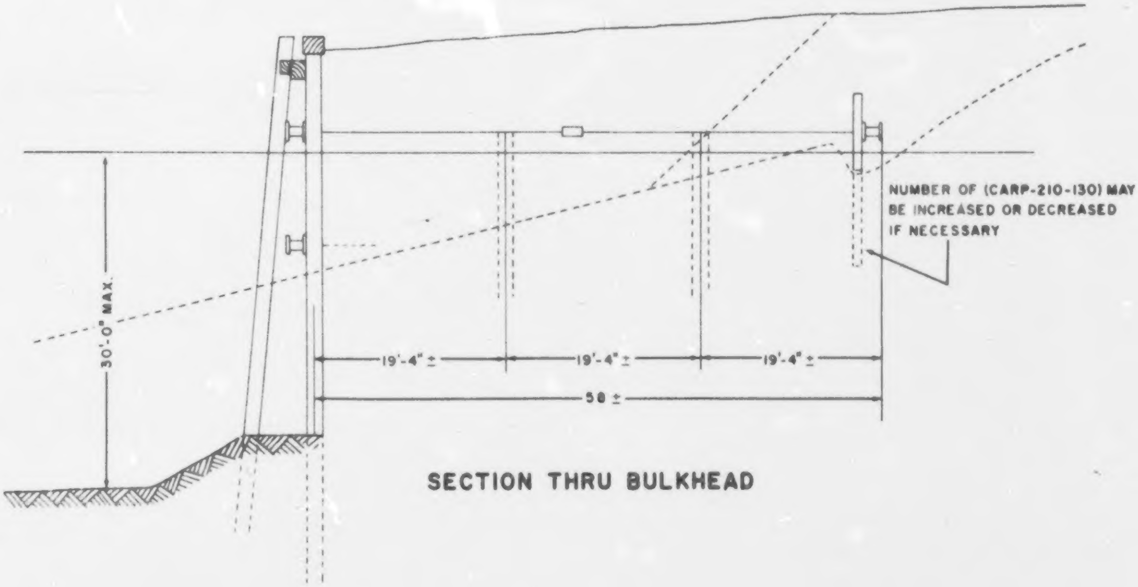
SAFETY

Safety is a matter of chief concern to everyone working at or around a sawmill. Accidents may mean serious injury or death to workers, as well as extensive damage to equipment. As a BU 1 or C, see that your men know the safety precautions to follow, and try to develop a safety-conscions attitude on the part of every member of your crew. Some of the primary precautions applicable to the transportable sawmill are given below.

1. Before cutting inspect the log for rocks, metal, loose bark and limbs.
2. Workmen and spectators must not stand directly behind the rear end-rail while the mill is in operation. Small pieces will sometimes shoot out of that end before the offbearing gate is in position. These pieces have pierced 3/4 inch plywood! The safest position from which to observe the operation of the mill is on the "B" column side of the log, to the right of the operator.
3. If the saws hit an obstruction embedded in the log, immediately shut off the power unit and manually push the saws back out of the cut. Inspect for damage and make any necessary repairs before restarting the power unit.


2-12" ⌶ 25#
1ϕX0'-4" PIPE SPACERS
7/8"ϕX0'-6" BOLTS
1 3/8"ϕX1'-4" BOLTS
4"X3/4"X0'-4" WASHER
4"X3/4"X0'-10" WASHER
STEEL SHEET PILING
ZP38 OR MZ38
STAGGER SPLICES IN UPPER
AND LOWER CHANNELS
SPLICE ℞ 9"X1/2"X1'-6"
6-BOLTS 7/8"ϕX0'-2 1/4"
2-BOLTS 7/8"ϕX0'-6"
2-PIPE SPACERS 1"ϕX0"-4'
TIE ROD (SFO-12) MAY BE SHORTENED
BY CUTTING & WELDING
WASHER 10"X1"X0'-10"
9'-0"

DETAIL PLAN OF BULKHEAD


NUMBER OF (CARP-210-130) MAY
BE INCREASED OR DECREASED
IF NECESSARY
30'-0" MAX.
19'-4" ±
19'-4" ±
19'-4" ±
58 ±

SECTION THRU BULKHEAD

45.534

Figure 8-51. –Working drawings for a steel sheet pile bulkhead.

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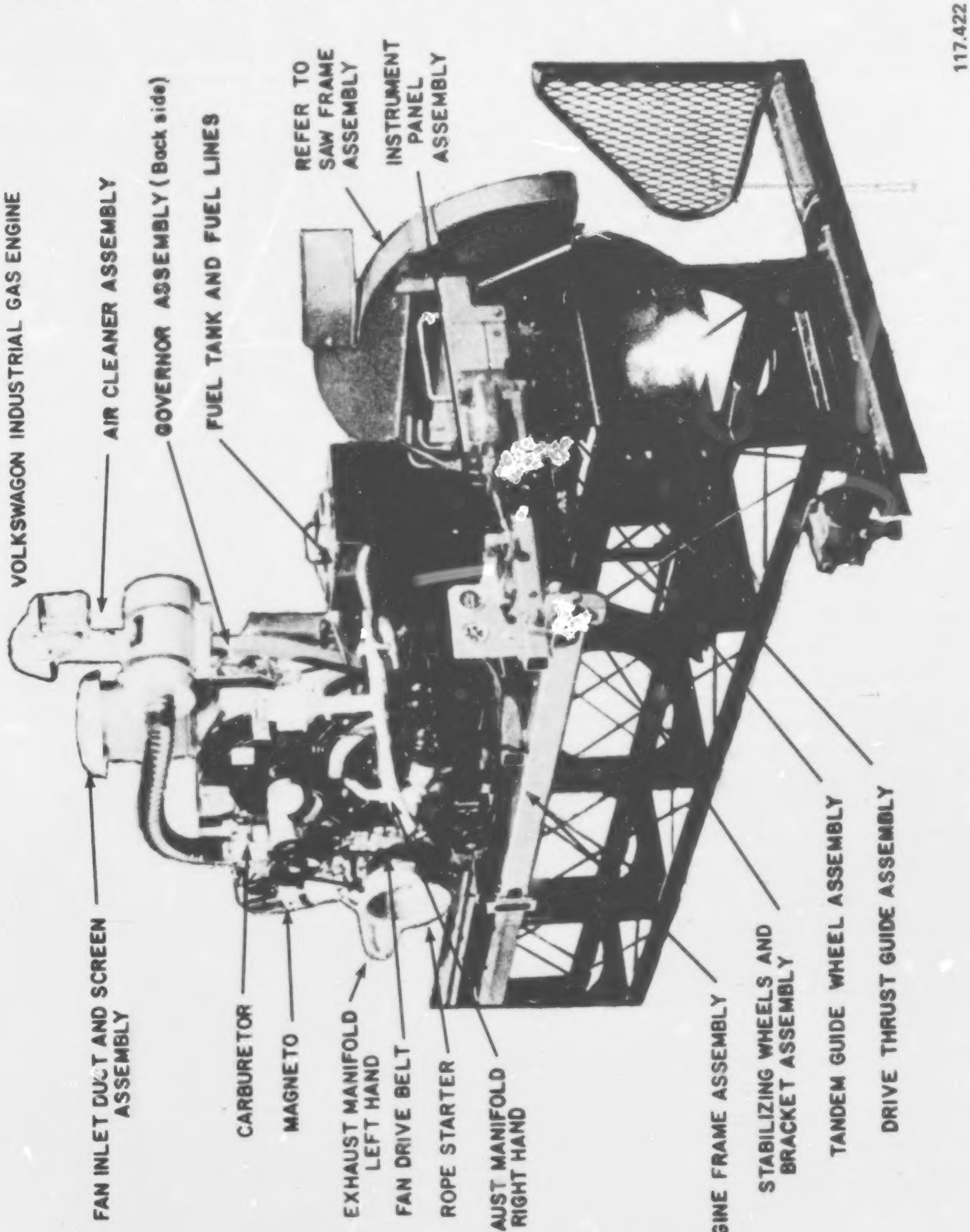
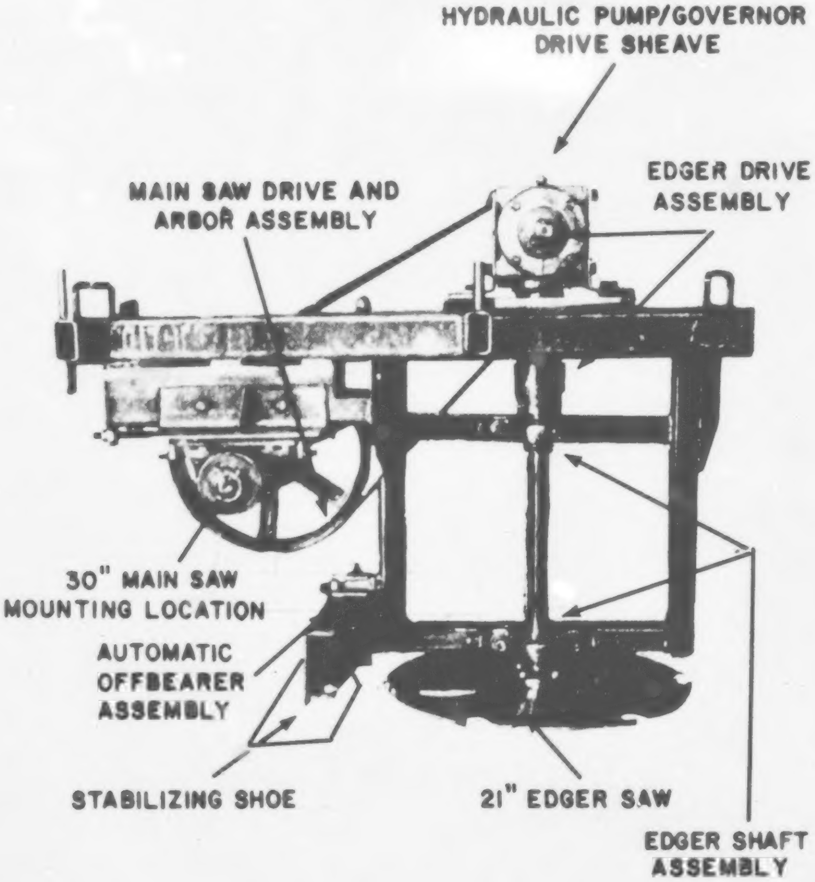

VOLKSWAGON INDUSTRIAL GAS ENGINE
AIR CLEANER ASSEMBLY
GOVERNOR ASSEMBLY (Back side)
FUEL TANK AND FUEL LINES
REFER TO SAW FRAME ASSEMBLY
INSTRUMENT PANEL ASSEMBLY
117.422
FAN INLET DUCT AND SCREEN ASSEMBLY
CARBURETOR
MAGNETO
EXHAUST MANIFOLD LEFT HAND
FAN DRIVE BELT
ROPE STARTER
EXHAUST MANIFOLD RIGHT HAND
ENGINE FRAME ASSEMBLY
STABILIZING WHEELS AND BRACKET ASSEMBLY
TANDEM GUIDE WHEEL ASSEMBLY
DRIVE THRUST GUIDE ASSEMBLY

Figure 8-52. —Engine and frame assembly.

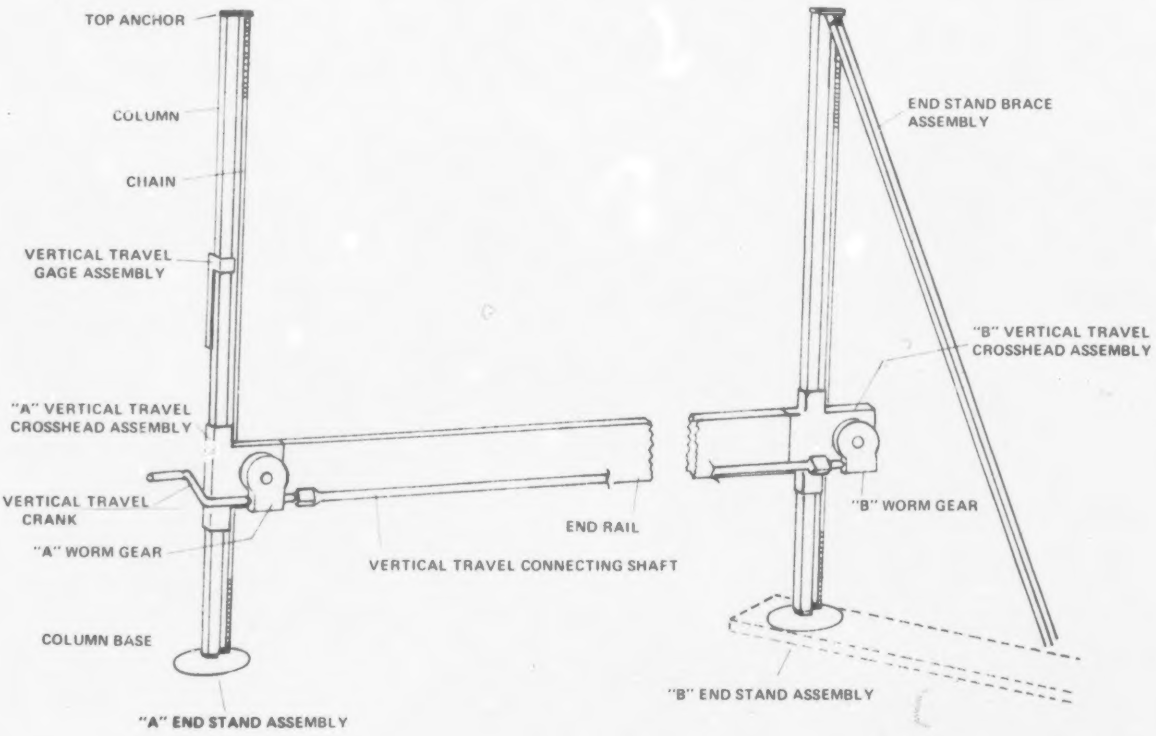

HYDRAULIC PUMP/GOVERNOR DRIVE SHEAVE
EDGER DRIVE ASSEMBLY
MAIN SAW DRIVE AND ARBOR ASSEMBLY
30" MAIN SAW MOUNTING LOCATION
AUTOMATIC OFFBEARER ASSEMBLY
STABILIZING SHOE
21" EDGER SAW
EDGER SHAFT ASSEMBLY

117.423

Figure 8-53.—Saw frame assembly.

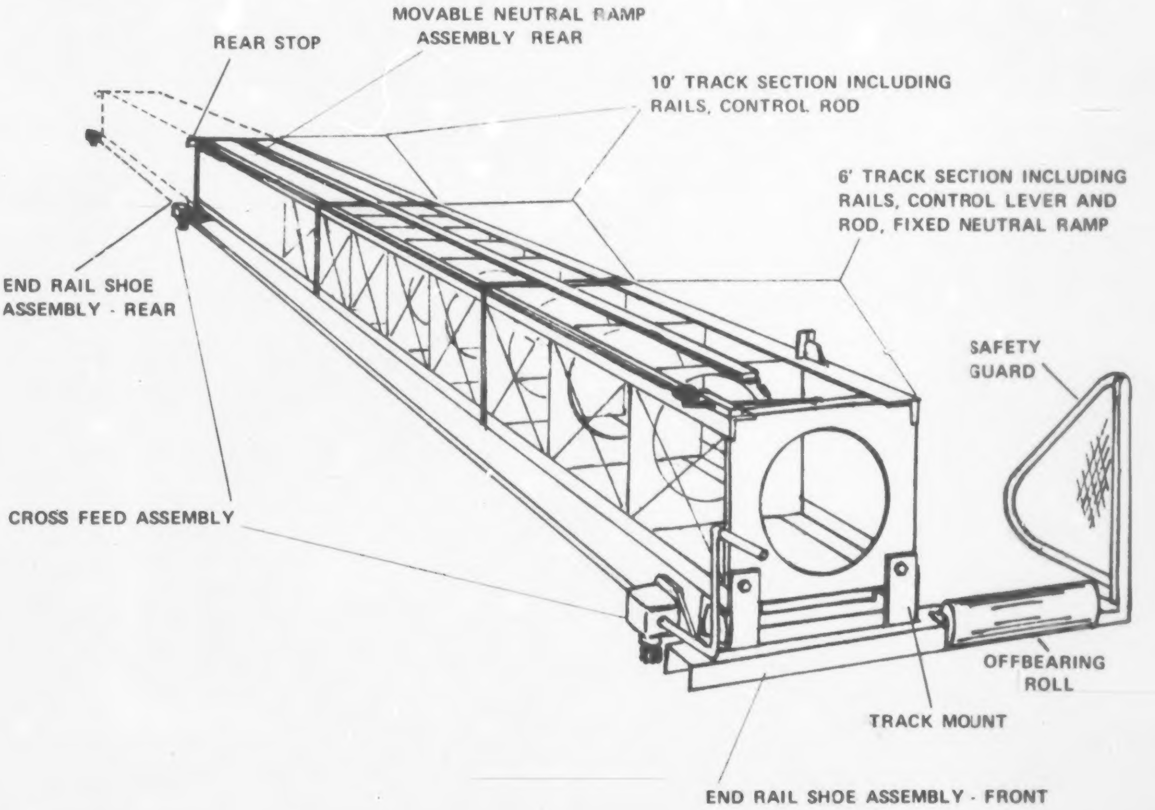
4. Care must be taken when making the last cut on the right side of the log so that when the edger cuts through at the end of the cut, the main blade doesn't shoot the piece out the front. The person handling the lumber should hang onto the piece until the main blade is clear.

5. Personnel involved in mill operations should wear proper fitting protective clothing, including safety shoes, goggles, and leather gloves.


TOP ANCHOR
COLUMN
CHAIN
VERTICAL TRAVEL GAGE ASSEMBLY
"A" VERTICAL TRAVEL CROSSHEAD ASSEMBLY
VERTICAL TRAVEL CRANK
"A" WORM GEAR
COLUMN BASE
"A" END STAND ASSEMBLY
END RAIL
VERTICAL TRAVEL CONNECTING SHAFT
END STAND BRACE ASSEMBLY
"B" VERTICAL TRAVEL CROSSHEAD ASSEMBLY
"B" WORM GEAR
"B" END STAND ASSEMBLY

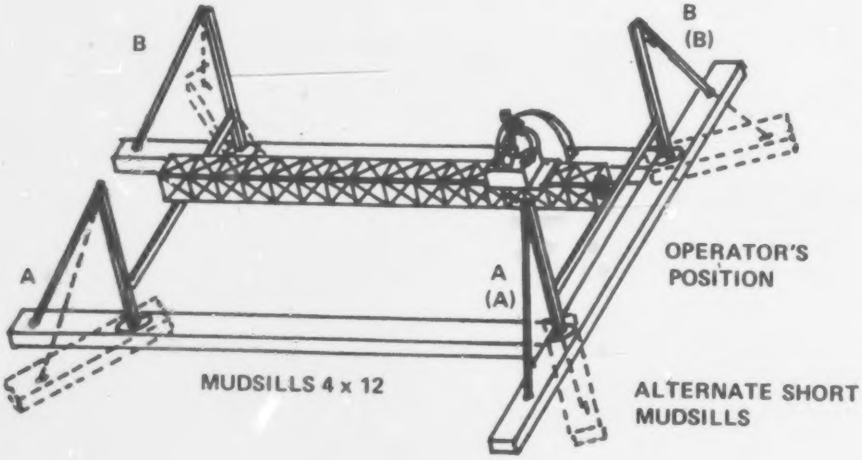
117.424

Figure 8-54. —Standard end stands assembly.


MOVABLE NEUTRAL RAMP ASSEMBLY REAR
REAR STOP
10' TRACK SECTION INCLUDING RAILS, CONTROL ROD
6' TRACK SECTION INCLUDING RAILS, CONTROL LEVER AND ROD, FIXED NEUTRAL RAMP
END RAIL SHOE ASSEMBLY - REAR
SAFETY GUARD
CROSS FEED ASSEMBLY
OFFBEARING ROLL
TRACK MOUNT
END RAIL SHOE ASSEMBLY - FRONT

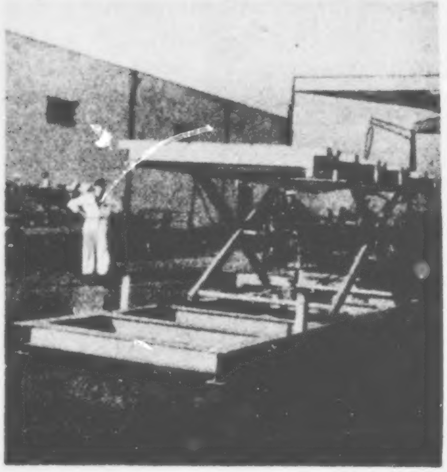
117.425

Figure 8-55. —Track assembly.


B
B
(B)
C
A
A
(A)
OPERATOR'S POSITION
MUDSILLS 4 x 12
ALTERNATE SHORT MUDSILLS

117.426

Figure 8-56. —Basic mill set up.



117.427

Figure 8-57. —Scissors type offbearing table.

CHAPTER 9

CONSTRUCTION INSPECTION: BUILDINGS

The Builder who is well qualified and has shown himself capable of handling responsibility may be called upon at times to serve as INSPECTOR of new construction projects. Information that will aid you in conducting inspections of new construction work is given in both this chapter and the one that follows. This chapter discusses responsibilities of the inspector, and points out items to be checked in inspecting various parts of buildings and other such structures. The next chapter deals with check points to be covered in inspecting additional types of structures, such as cofferdams, bridges, and pavements. You may also have occasion to conduct maintenance inspections of existing structures; however, information relative to the inspection of existing structures is presented in chapter 11. Bear in mind that the subject of inspections is broad in scope, so it is not intended to point out every item to be covered in making an inspection. In addition to the check points given here, other important points may need to be included in your inspection, depending upon local regulations, special requirements, and so on.

RESPONSIBILITIES OF INSPECTOR

The prime function and responsibility of the inspector is to assure that the work is performed in all respects in accordance with the drawings and specifications. These requirements are usually–but not always–sufficiently exacting to necessitate high standards of quality, both in materials and workmanship. In the case of temporary or emergency construction, quality requirements may be lowered intentionally. The inspector, therefore, must be careful to ascertain that the work is of the required quality, but he also must be equally careful not to demand a quality of work superior to that required.

In some cases the specifications for the project, or the standard specifications included therein by reference, may establish definite tolerances over or under the exact measurements that will be accepted, and the inspector then has only to verify that the work is within the specified limits. On most phases of the work, however, specific tolerances cannot be fixed, and intelligent judgment is required in interpreting such requirements as plumb, true, level, and perfect. The intention is that workmanship shall be of the most suitable grade for the purpose. The inspector, therefore, should have a comprehensive practical knowledge of the grades of workmanship appropriate in the various classes of structures and in the various details of the work.

The degree of accuracy appropriate is dependent on many factors. Structural framing may have to be true within 1/16 inch, or in some cases within 1/8 inch. Concrete work can seldom be held closer than 1/8 inch, and in some special types of structures much larger tolerances must be permitted and allowed for.

The inspector must assure himself that the principal centerlines, column lines, and controlling overall dimensions and elevations are correct; that minor errors are not permitted to accumulate but are compensated for continuously; that exposed work is visually acceptable; and that special care is taken when greater than ordinary precision for the type of work is necessary for some special reason.

It is important that the inspector make clear at the outset of the work what will be expected and make sure that the initial portions of the work fulfill these expectations. It will invariably be found that the standards of accuracy established and enforced during the first few days work will set the pattern for the rest of the work. The inspector must be consistent in the standards he exacts. He must be reasonable, but he cannot be lenient in this respect.

Inspection of temporary construction must be limited to that sufficient to assure that the work is adequate and safe for the purpose. The inspector should, however, be alert to note any defective construction, unsound materials, possible weaknesses, and hazards and call them to the attention of his superior.

The inspector is responsible for the effective application of the safety program to functions on which he is assigned. This responsibility covers the prevention of accidents causing physical injury, or property damage. In the event the inspector encounters difficulty in correcting an existing hazard, safety violation, or preventing a future hazard, he should immediately report such a condition to his superior for proper action and/or guidance.

An extremely important and relatively difficult phase of inspection is in the checking of a project as it nears completion to make sure that every item required for the completion of the project has actually been provided. It is essential that a check-off system be used for this purpose and that the system adopted be initiated early enough so that ample time will be available for delivery and installation of any items overlooked. This is particularly necessary in times of emergency when long lead time between ordering and delivery is encountered for many critical items of material and equipment. The inspector must maintain strict watch over cleanup items, particularly where portions of the work may be concealed in later stages. Because of the inherent tendency of construction projects to drag out to a slow finish, the inspector will have to exert correspondingly greater pressure to obtain full and expeditious compliance with the requirements in this respect.

The inspector may be responsible for maintaining accurate and detailed records of performance of the work and of various pertinent matters. Records and reports should be in clear and complete form so that no possible misinterpretation of the facts or uncertainty as to events may arise therefrom.

The inspector has contact with other people and this calls for an understanding of human relations. He must use tact and courtesy in dealing with others. If he gives criticism, he should do so constructively and in a manner that will not cause resentment. He must avoid showing any favoritism or partiality, and particularly he must avoid making any statements or taking any action that might discredit any supervisor or foreman before his subordinates.

It is imperative that the inspector conduct himself at all times in a manner commensurate with the highly responsible position he occupies. He must be absolutely honest in his dealings with others. Integrity is a fundamental requisite. He must be trustworthy, loyal, diligent, and punctual. He must be dignified, steady, and poised in all his actions. When his job involves supervising others, the inspector must be firm but fair in handling his subordinates. He must maintain his self-respect and win the respect of all his associates, keeping in mind that a harmonious relationship is more successful than one hampered by friction and discord.

INSPECTING WORK AREAS, TOOLS, AND EQUIPMENT

When inspecting work areas, tools and equipment, the inspector should endeavor to see that all necessary precautions are taken to ensure the safety of personnel. Some pointers that will aid you, as an inspector, in making safety inspections of work areas, tools, and equipment are given below. You may also find these pointers useful in supervising construction operations.

WORK AREAS

When making a safety inspection of work areas, the inspector should watch carefully for potential hazards and unsafe conditions. Some of the check points to include in an inspection of work areas are as follows:

Ensure that equipment is arranged to permit working on material with a minimum of handling and so that work can flow in an orderly and logical sequence. In addition, see that clearances around the equipment are ample to prevent congestion and avoid interference with operation of other equipment.

Make sure materials are properly stored and walkways are kept clear. Materials should be piled so that they cannot roll, fall, tumble, or be blown over.

Be especially watchful of housekeeping practices in work areas and ensure that potential hazards to personnel and others are corrected immediately. Work areas should be kept clean and orderly at all times. Oily rags and other such debris should be disposed of in approved safety containers. See that small parts, tools or equipment–such as bolts, nuts, and wrenches–are not left lying around where someone may fall over them.

Ensure that planks, timbers, or blocks containing projecting nails are removed immediately from the jobsite or placed in orderly piles where personnel are not likely to stumble or fall over them.

Check carefully to see that individuals observe all applicable safety precautions in performing their duties. In doing so, ensure that personnel wear personal protective apparel, such as goggles, safety belts, helmets, gloves, and safety shoes, on jobs where required. See that safety equipment, such as safety screens and ventilating equipment is used on operations where required.

Make sure that warning signals are placed as necessary to provide proper and adequate warning of hazards. Signs should be removed as soon as the hazards have been eliminated.

TOOLS AND EQUIPMENT

When inspecting hand and portable tools, the inspector should ensure that they are in safe and proper working condition. Some of the check points to cover when inspecting tools are as follows:

Ensure that tools are used only for their proper purpose and in the manner prescribed.

See that handles of all handtools are free from slivers or other defects. Note: defective handles should not be repaired by taping.

Check closely to see that gripping surfaces of tools are kept free of grease, oil, or other slippery materials.

Ensure that defective or damaged tools are not used, and see that they are repaired or disposed of immediately.

See that power tools are used only when the user is in a secure working position and braced against falling. Sudden cessation of operation, or kicking or bucking of the tool may result in a fall.

Make sure that operators of drills, reamers, and other rotating tools do not wear loose clothing with free ends, neckties, or gloves.

See that power machines are operated only by qualified personnel; that guards are kept in place during operation of machines; and that hands, as well as tools, are kept clear of all moving parts of a machine while it is in operation.

Tools left lying around on benches, near machines, and on floors and ladders cause accidents–and get lost. See that tools are returned to their proper place of storage when no longer needed on a job.

Mushroomed and burred heads on striking tools can cause serious injury–see that those heads are ground down.

Ensure that all power tools are grounded. On three-prong plugs this is done automatically when the plug is inserted. On tools using the standard two-prong plug there may be a built-in third wire in the cord with a clip on it. This clip should be firmly attached to a water pipe or other grounded object before the plug is inserted. If there is no clip coming out of the cord, the tool can be grounded by attaching one end of a wire to the metal frame of the tool and the other end to a grounded structure.

FOUNDATIONS

Various types of foundations are used for buildings. With space being limited, let us consider only two of the main types–mat foundations and spread footings.

MAT FOUNDATIONS

Mat foundations are normally used when the subsoil is not considered good enough for spread footings and when the area involved is so large that piles would contribute so little to the supporting power of the ground in comparison with their cost as to be uneconomical. Mat foundations may take the form of a hollow concrete box with intermediate walls or columns to permit taking advantage of the weight of earth removed in the excavation to offset in part the load imposed on the mat foundations. The inspector must make sure that the subgrade is carefully leveled to the specified elevation so that the concrete will be of full thickness and that special sand or gravel is spread and compacted if called for. The inspector should be alert to detect any wide variations in the quality of the subgrade. Concrete for mat foundations will usually be specified as conforming to NAVFAC Specification 13Y. In chapter 10, the section entitled "Concrete Construction" contains various factors that will apply in the inspection of mat foundations.

SPREAD FOOTINGS

Spread footings are designed for definite load per square foot, based on prior investigations of the site, or on general knowledge of the characteristics of the soil in the area. Usually the drawings indicate both the sizes of the various footings and the loading on which they are based. The inspector's primary function is simply to assure the correct size of the footings, with satisfactory concrete reinforcement, or other parts as shown or specified. The inspector should be alert, however, to detect any significant variations in the quality of the substrata from that indicated by boring records or assumed designed loadings.

Spread footings must be constructed in the dry, except when the project specifications provide otherwise. Excavations must be dewatered by pumping from sumps located outside the limits of the footing, or by well pointing. In such cases, the inspector must make sure that the surface of the subgrade on which the footing is built is not unduly softened and weakened by the presence of an excess of moisture. If such conditions exist, he must see that the unsuitable material is removed and replaced with satisfactory material as specified for such conditions. If the specifications do not cover this case, replacement with lean concrete should be required.

Heavy foundations frequently require the provision of a steel grillage to distribute the concentrated load of the column. Such grillages will be required either under spread footings, or more frequently, under footings supported by piles, caissons, or other deep supports. When grillages are required by the drawings and specifications, the inspector must make sure that they are carefully fabricated, adequately painted or coated as specified, truly located, aligned and leveled, provided with all necessary anchor bolts in true vertical position, and bedded firmly and thoroughly in the footing.

It is essential that anchor bolts be set with the utmost accuracy in respect to both position and level. Errors discovered after the concrete has set are extremely expensive to correct. This is particularly vital when sleeves are not specified or permitted to allow for lateral play. Anchor bolts are usually set to a template, which is carefully aligned with the building lines and leveled to a definite elevation. The inspector must check the setting and verify beyond question that it is accurate within permissible tolerances before permitting concreting to proceed. The templates should be checked periodically during the course of the work to make sure that they have not been disturbed. Particular attention must be paid to the bolt settings to make certain that there is sufficient thread exposed above the top of the steel base plate to permit full engagement of the nuts without excessive projection of the threaded bolt. The inspector must also make sure that the anchor bolts are provided with hooks, L-bends, swaging, or other anchorage devices as shown or specified. When sleeves are specified, the inspector should make sure that the bolts are centrally located in the sleeves to provide leeway in adjustment in all directions. He must ensure that the sleeves are NOT installed in such manner as to decrease the holding power of the bolts. Care must also be taken later to make sure that the sleeves are properly filled with grout, lead, or sulfur, as the specifications may require, after the steel has been erected and aligned.

Concrete for footings will usually be specified as conforming to NAVFAC Specification 13Y.

In chapter 10, the section on "Concrete Construction" contains various factors that will apply in the inspection of concrete for spread footings, as well as mat foundations.

Care must be taken to ensure that all wood and debris are removed from around the footings, that clean earth free from objectionable material is used for BACKFILL, and that this fill is thoroughly compacted to substantially the same density as the surrounding undisturbed earth. This is particularly important when pavement or floors are to be built adjacent to the footing, to avoid differential settlement.

FRAMING

Several types of framing are used in construction work. Our discussion here is limited to two types of framing: concrete and wood.

CONCRETE FRAMING

Concrete framing for buildings generally consists of columns, girders, beams, and slabs. Flat-slab construction consists of columns, capitals, plinths, and slabs, with girders and beams used only to frame around openings and to support spandrel walls. Metal pan construction may also be used for floors. Increased use may be made of prestressed concrete construction in the future.

On building construction, the inspector must assure that all wall ties, anchors, inserts, and other appliances for fastening appurtenances are installed in the forms in the exact locations needed and that all openings for pipes, ducts, vents, and other purposes are formed in the correct locations. A thorough check must be made, before permission is given to start concreting, to assure that no item has been overlooked.

Special attention must be paid on building work to the accuracy of alignment, trueness of exposed surfaces, and finish. The inspector must assure that change of floor levels caused by shrinkage of columns is fully compensated for. He must give close attention to location of construction joints and of expansion joints, if required, and be certain that the latter are extended through the structure and provide the clear opening indicated. He must make sure that slab forms are kept in position for the full period specified and that forms under beam and girder soffits are kept in place for the additional period required. He must make certain that all concrete is cured in the proper manner and for the full period prescribed.

WOOD FRAMING

Wood framing is widely used, particularly for emergency and temporary construction. Quarters and temporary barracks may be of typical frame-house construction. Storehouses, particularly of the large one-story type, may have frames of wood posts, beams, and joists, with wood roof sheathing. Shop buildings may have to be built of wood when steel and concrete are not available. Such structures may require heavy built-up timber columns and trusses, particularly if crane runways have to be provided. Large wooden hangars have been built, necessitating trusses, with each member consisting of a number of heavy planks. Drill halls and similar structures requiring wide-span construction have occasionally been framed with laminated wood arches consisting of a large number of plies of relatively thin planks glued together with a special waterproof and durable glue. Many other special types of framing may be encountered, such as slow-burning mill construction, lamella roof arches, and rigid frames.

The inspector must familiarize himself fully with the drawings and specifications and the standard specifications referenced therein. He must make sure that framing of the type shown or specified is provided and that all wood is of the species, grade, size, and surfacing specified and has been inspected and grade marked.

The inspector must make certain that nails, bolts, screws, connector rings, and other fastenings conform to requirements in type and size. He must ensure that metal ties, straps, hangers, stirrups, joist hangers, and similar accessories are suitable and correctly used. Where numerous plies of lumber are held together by long through bolts, the inspector should recheck the tightness of the nuts before the project is finally accepted because shrinkage of the lumber may cause them to loosen.

WALLS

Walls are made of a wide variety of materials, so detailed information on wall construction cannot be given here. With space being limited, only three types of wall will be discussed here; they are block walls, stucco walls, and wood walls.

BLOCK

Concrete blocks, also called concrete masonry units, are made with stone, gravel, shale, slag, or cinders as the coarse aggregate. Units usually are made with nominal widths of 3, 4, 6, 8, 10, or 12 inches. Walls and webs usually are 2 inches in nominal thickness, but actual thicknesses may run 1/4 to 3/8 inch less. Units are made with 2, 3, 4, and 6 cores. They are also manufactured in half units and in special units, such as jamb blocks, end blocks, headers, and double corner units.

In construction involving the use of concrete block, the inspector must check all material for damage, imperfections, stains, color, size, and marking. He must make certain that only material conforming fully with requirements is used in the work. He should verify the course heights, bond, color pattern, and similar basic requirements.

The inspector must make sure that all masonry units are carefully handled at all stages of the work, to preclude damage, and that scaffolds and floors are not overloaded by stacking them too heavily.

The inspector must determine that joints conform to the specifications in materials, type, pointing, and finish. To assure sound watertight construction, he must make sure that each joint is completely filled for its entire length and depth, is free from voids, and is correctly struck without excessive troweling. He must make sure that the horizontal joints are truly level and that the vertical joints are broken, staggered, or patterned as prescribed or shown.

The inspector must determine that all joints are tooled to the prescribed form, if so specified. Where pointing is prescribed, the inspector must assure that the mortar joints are raked out to the specified depth, saturated with clean water, refilled solidly with mortar, and tooled. He must require that all surplus mortar and stains be removed as the work progresses. He should assure that horizontal or bed joints are finished first and then the vertical joints.

The inspector should make sure that exposed surfaces of masonry units are washed with water and brushed with a stiff brush until all mortar stains have been removed. A weak solution of muriatic acid may be used for stubborn stains, but care should be exercised to require thorough flushing with clean water. Finished terra cotta facing should be cleaned with a stiff brush, using soap powder boiled in water. The brushing should be continued until all stains and dirt are removed. The facing should then be rinsed thoroughly with clean water. The inspector should not permit the use of wire brushes, abrasives, or metal tools because they may damage the surface, color, edges, and joints.

STUCCO

Stucco usually is specified as composed of portland cement, hydrated lime, sand and water and may have integral waterproofing or coloring pigment added. Painted or galvanized metal lath, expanded metal, or wire mesh is used for the support of stucco, except on masonry walls, and requires nails, staples, and tie wire for fastenings. The inspector must make certain that all material conforms to the requirements of the project specifications and the referenced standard specifications.

Stucco may be applied on masonry, concrete, or wood frame walls. The inspector must make sure that the masonry has an unglazed rough surface with joints struck flush and adequate keys to assure good bond. Concrete is often given a "dash" coat of neat cement and sand before the stucco is applied. If the base is wood frame walls, the inspector must determine that the lath or wire is securely fastened to the framing and tied together to form a taut, strong support for the stucco. Specifications usually will require application in three coats: scratch, brown, and finish.

The inspector must make sure that all masonry joints are filled, struck smooth, and allowed to set prior to applying the SCRATCH COAT. He must make certain that the SCRATCH COAT is pressed thoroughly into the joints of the masonry or into the openings of metal or wire lath to assure adequate key and bond. He must determine that this coat is applied carefully to level and plumb irregularities, that it is scored or combed after completion to provide good bond, and that it is permitted to dry for the specified period.

The BROWN COAT is usually of the same composition as the scratch coat. The inspector must make sure that the scratch coat is wetted immediately before the brown coat is started; that the brown coat is applied, rodded, and floated to bring all surfaces to true flat plumb planes; that the surface is combed by fine cross-hatching to provide a bond for the finish coat; and that the coat is permitted to dry for the prescribed period.

The FINAL COAT, also called the finish coat, is a relatively thin coat of special composition to provide the finished surface, texture, and color. The inspector must make sure that this coat conforms to the specifications in composition, including colored aggregate, pigment, and integral waterproofing, if prescribed; that it is carefully applied to assure true plane or curved surfaces and sharp edges; and that on completion it is protected from excessive heat and kept moistened for the specified period to preclude hair cracks, crazing, and checking.

The inspector must make sure that all surfaces are true; that the surface texture conforms to the finish specified and to the approved sample, if any; and that the color is of a permanent type, is thoroughly incorporated in the finish coat, and matches, after the stucco is dry, the color specified or indicated by a previously approved sample.

WOOD

Wood walls are used for temporary or emergency-type construction of barracks, messhalls, and other buildings. Siding used is of a wide variety of patterns, such as clapboards, drop siding, shiplap, bevel, or tongue-and-groove. Board and batten construction is used either for emergency construction or for architectural effect on quarters, the boards being installed vertically, with the battens covering the joints. Shingles are used occasionally.

The inspector must make sure that the wall material conforms to the specifications as to the kind of wood, grade, and manufacture or has been inspected or grade marked. He must assure that wall sheathing is tight, covered with building or sheathing paper, and flashed as necessary for weathertightness. He must make certain that siding is applied carefully so that lines are straight and true and that laps and exposed faces are correct. Also, he must make sure that nails are of the specified kind and weight, are driven flush, recessed, or blind as prescribed and that, if recessed, they are filled over with a suitable plastic wood putty.

On board and batten construction, the inspector must make sure that boards are set tightly together, with joints truly vertical; that battens are truly vertical and truly centered over the joints; and that both boards and battens are securely nailed as prescribed. At corners, he should ensure that the board on one side laps over the end of the board on the other side and that two battens are used, each covering the previous joint.

On shingled walls the inspector must determine that shingles are of the correct length and butt thickness; that starter courses are correctly set on drips, or doubled, as specified; that all horizontal lines are true; that shingle exposure is as shown or specified; that shingles are laid with tight or slightly open joints as prescribed; that shingles are nailed above the butt line of the next course above with the prescribed number of nails of specified material, type, and weight; that all flashings and valley gutters required are correctly installed; and that ridge and hip cover shingles are placed and nailed securely as shown.

WOOD ROOFS

You may have occasion to inspect various types of roofs including concrete, corrugated metal, wood, and so on. In a chapter so broad in scope as this one, we will not attempt coverage on all the different types of roofs. The subject will be limited, therefore, to one type—wood roofs.

The inspector must make sure that all lumber for wood roofs has been factory inspected, association inspected, or grade marked. If not, he must determine that all lumber is of the kind, size, grade, and manufacture specified.

When inspecting the pitched roof, the inspector must be certain that all framing is cut accurately to exact length and beveled or mitered as necessary to assure full even bearing for the entire length of the cut at all meeting faces and is correctly and securely nailed. He must make sure that all bracing, trussing, collar beams, and king posts are provided as shown or specified and are securely nailed or bolted with steel straps or wood splice plates or collars as detailed.

When inspecting the flat roof, the inspector must be sure that the roof is constructed flat or sloped to drain, as prescribed. The inspector must be sure that rafters are cross-bridged in the manner and at the intervals shown or specified. He must ascertain that rafters extending into masonry walls with parapets are bevel cut, so that the end is flush with the wall at the top of the rafter and provides full bearing at the bottom of the rafter.

The inspector must make certain that SHEATHING is laid tight and straight and is thoroughly nailed as prescribed. He should be sure that sheathing on pitched roofs is started at the eaves, with the boards laid horizontally, that tongue-and-groove sheathing is laid with the tongue up, and that shiplap sheathing is laid with the lower tongue lapping the tongue of the board below and the upper tongue against the rafters to minimize leakage. If plywood sheathing is specified or permitted, the inspector must determine that the material conforms to requirements, particularly with respect to the waterproof glue. Plywood should be laid with the face grain perpendicular to the rafters, with horizontal joints supported on headers cut in between rafters, and with vertical joints staggered at midsheet intervals. The inspector must make sure that plywood is applied as shown or specified and is nailed at each bearing with closely spaced nails.

ROOFING

A number of different types of roofing are used on structures. One of the main types found on Navy-built structures is BUILT-UP ROOFING, specifications for which are contained in NAVFAC Specification 7Y. It is with this type that we are concerned in this discussion.

Built-up roofing, as the name implies, is a membrane built up on the job from alternate layers of bitumen-saturated felt and bitumen. Because each roof is custom made, the importance of good workmanship cannot be overemphasized.

In inspecting built-up roofing the inspector should verify the particular combination of plies, felt, binder, and cover prescribed by the project specifications.

The inspector must be sure that the felt conforms to requirements in kind, grade, weight, and other specified characteristics and that the material as used is not crushed, torn, or otherwise damaged.

The inspector must ensure that the primer and binder furnished are asphalt or tar as prescribed. He must, also, see that the material conforms to the specification requirements for the prescribed type and is kept free from water, oil, and dirt.

The standard specifications limit the material used for surfacing to gravel or slag. The project specifications may permit or prescribe a special material such as white marble chips. The inspector must verify the types of material prescribed or permitted and assure that the material furnished conforms and is of suitable size, gradation, and cleanliness. No surfacing is required for roofing using asbestos felt.

Where a wood roof is concerned, the inspector must make sure that the roof deck has been prepared suitably to receive the roofing before permitting laying of the roofing to be started. He must ascertain that all large cracks and knotholes have been covered with tin nailed in place and make sure the roof is suitably smooth, clean, and dry. He must be certain that felt or metal valley lining is installed in all valleys, as prescribed for the type of roofing being used. He must be sure that the roof is covered with a layer of unimpregnated felt or resin-sized building paper and then covered with two layers of saturated felt, all lapped, nailed, mopped, and turned up or cut off at junctions with vertical surfaces as prescribed.

Where concrete, poured gypsum, and similar roofs are concerned, the inspector must ensure that all cracks, voids, and rough spots are filled level and smooth with grout and are thoroughly dry; that all sharp or rough edges are smoothed; that all loose mortar and concrete are removed; and that the surface is broom clean. He must be sure that felt or metal valley lining is installed in all valleys, as prescribed for the type of roofing being used. He must determine that the roof is covered with a primer of hot pitch or asphalt and then covered with two layers of saturated felt, all lapped, mopped, and turned up or cut off at junctions with vertical surfaces as prescribed. On precast gypsum or nailable concrete roofs, the specifications may prescribe that these first two plies be nailed.

With all roofs, the inspector must be certain that additional layers of binder and felt are applied as required by the specifications. He must make sure that each lap and layer are mopped full width with the prescribed quantity of hot binder, without gaps, so that felt nowhere touches felt; that the binder is applied at a temperature within the specified range and that no burnt tar or asphalt is used; and that these layers are turned up as prescribed. He must be sure that the entire finished surface is uniformly coated with binder poured on at the prescribed rate and then covered with the prescribed quantity and kind of covering material. The inspector must make sure that all roofing is free from wrinkles, air or water bubbles, and similar irregularities and that all plies are firmly cemented together.

FLOORS

You will find various types of floors in Navy structures. Two common types frequently installed, and which you may have to inspect, are concrete floors and wood floors.

CONCRETE

Concrete floors may be built on the ground at grade or on fill over membrane waterproofing. Structural concrete floors may be of flat-slab, beam and slab, beam and girder, or metal-pan type.

On floor construction the inspector must be sure that forms and supports are designed and installed so that they are readily adjusted to exact grade. He must ensure that slab forms and beam and girder side forms can be removed after the prescribed curing period without disturbing the forms under the soffits of beams and girders or these form supports. The inspector should never permit removal of soffit forms and supports and reshoring in advance of the time specified. He must make certain that all forms are accurately and adequately constructed, are adjusted to exact grade, are lined with absorptive lining if prescribed, and are oiled or otherwise treated as prescribed. Special care must be taken to secure clean true surfaces with straight edges and uniform chamfers if the underside of the structural floor will be exposed in the finished work. The inspector must check the work to make sure that all inserts, hangers, anchors, sleeves, and other fittings are provided as required and are accurately located.

An inspection should cover the requirements for inspection of placing of concrete, which are given in chapter 10 in the section on "Concrete Construction." In addition, special care must be taken with concrete floors on grade for frame superstructures to assure that termiteproof construction is obtained. Usually this protection consists of a two-ply membrane waterproofing, laid on a course of pea gravel to break capillary action. The inspector must make sure that this membrane is completely continuous, is thoroughly sealed whenever pipes or conduits pass through the floor, and is extended into the exterior walls and finished as shown or specified.

The inspector must be sure that curing is performed as prescribed in the appropriate NavFac specification or in the project specifications. He should see that forms and form supports are left in place for the minimum length of time prescribed, respectively, for slabs, beam and girder sides, and beam and girder soffits. In addition, the inspector must note particularly any concrete that may have been frozen and report the circumstances and conditions to the proper authority.

WOOD

Wood floors for buildings of frame construction usually consist of finished flooring laid on subflooring that is supported on floor joists. Wood floors for slow-burning or mill construction usually consist of planks surfaced four sides, laid on edge with tight joints, and supported on floor beams of dimension timber spaced at fairly long spans.

The inspector must make sure that all lumber has been factory inspected, association grade marked, or otherwise inspected satisfactorily before delivery. If not, he must make sure that lumber is of the kind, grade, and manufacture prescribed and require removal of all unsuitable material. He must be sure that all beams are truly cut and have full square bearing over supports, with bolsters as shown. He must determine that the flooring is installed on edge, driven tightly together, and nailed together and fastened to the beams as indicated. He should be sure that butt joints are staggered if, and as, specified. After the floor is installed, he must make certain that it is planed and sanded to a level, even surface.

The inspector must be sure that floor joists are of correct size and overall length, are sound and free from excessive warp, and are installed bearing on sills or beams or supported therefrom by strap hangers, as shown. He must make sure that joists are braced with cross bridging and/or with solid bridging as prescribed. He must ensure that the tops of floor joists are brought to a true level plane; that subflooring of the specified kind, grade, and size is installed, made tight, and thoroughly nailed; and that building paper is laid if and as prescribed.

Wood floors are frequently installed on steel framing, particularly in light industrial buildings where steel bar joists are used. In some cases, floor joists are installed on the steelwork and the wood floor construction is otherwise the same as for frame construction. In other cases, floor decking consisting of heavy planking with square, shiplap, or tongue-and-groove joints is laid, driven tight, and bolted directly to the steelwork with carriage bolts. The inspector must make sure that all materials and workmanship conform to the requirements of the specifications and that the floor is finished smooth and even.

PARTITIONS

Partitions are required in many structures and should be carefully checked by the inspector. A variety of materials are used in the construction of partitions, including block, tile, and wood; it is with these materials that we are concerned in this discussion.

BLOCK AND TILE

In regards to block and tile, you can expect to encounter partitions made of hollow tile, gypsum block, concrete block, and glazed tile. You should be familiar with each type material and requirements for inspecting the installation of each type.

Hollow Tile

Hollow tile partitions are usually nonload-bearing and may be laid up with webs vertical or horizontal. The specifications will usually prescribe which method is to be used. Installations with webs vertical provide somewhat greater strength, whereas those with webs horizontal provide for full mortar beds and somewhat easier laying. Partitions vary from 3 to 12 inches in thickness, depending on the unsupported height and class of construction. They are laid up with tile having scored or smooth faces, depending on whether the tile is to be plastered or otherwise concealed, or is to be left with one or both faces exposed. Scored tile may occasionally be permitted for exposed work on basement partitions.

Hollow tile is made from burnt clay or shale and is available in two types, load-bearing and nonload-bearing, and in a number of arrangements of cells. The inspector must make sure that the tile furnished conforms to the project specifications and to the standard specifications referenced therein. He must see that cracked, broken, underburnt, or otherwise defective or damaged tiles are not used. He must also be sure that scored or smooth tile is used in the various locations as prescribed.

In regards to the INSTALLATION of hollow tile partitions, the inspector must be sure that partition lines are accurately marked out on floors and carefully checked for dimensions and squareness of corners before laying of tile is started. He must assure that dowels or anchors are set in the floor at suitable intervals to come at the joints of the first course, if prescribed. He must make certain that mortar of the specified mix and correct consistency is used; that the tiles are laid up in level courses, with vertical joints staggered; that the wall as built is plumb, true, and free from wind; and that anchors or expansion devices are installed at the ends and at the juncture with the ceiling. If specified, he must be sure that expansion joint material or other compressible layer is installed between the top of the partition and the floor slab above to preclude imposition of excessive load by the deflection or settlement of the floor above. He must make certain that all joints are slushed full of mortar. If the faces are to be left exposed, he must be sure that all joints are neatly tooled and that all faces are cleaned of mortar and other objectionable matter.

Gypsum Blocks

Gypsum blocks are widely used for partitions, particularly where relatively light and easily removable partitions are required. They are furnished in blocks of large size and from 3 to 8 inches in width, and usually have a series of circular holes parallel to the short dimension.

The inspector must make sure that the block conforms to the project specifications or to the standard specifications referenced therein; that damaged blocks are not used; and that mortar, usually gypsum or plaster of paris, is prepared and used as prescribed.

Requirements for inspecting the installation of gypsum block partitions are similar to those described above for hollow tile partitions.

Concrete Block

Concrete blocks are used extensively for partitions, particularly in areas where other types are not produced locally and are not competitive in price because of freight costs. They are made with stone or gravel, cinder, slag, or lightweight aggregates, in various sizes and in a number of cell arrangements and wall thicknesses.

The inspector must be certain that block, mortar, and hardware conform to the project specifications or to the standard specifications referenced therein, and that blocks are sound and undamaged when used. If blocks are to be left exposed, he must be sure that the surface texture is uniform and of suitable character and color.

Requirements for inspecting the installation of concrete block partitions are similar to those described earlier for hollow tile partitions.

Glazed Tile

Glazed tile is used for partitions and for interior facing of walls where a hard, impervious, glossy surface is needed for sanitary purposes, ease of cleaning, or decorative effect. There are several distinct types of tile used for these purposes, such as ceramic tile, architectural tile, and salt-glazed tile. The latter is the type usually prescribed. Tile is furnished with one face glazed or with both faces glazed. The latter is used for thin partitions, usually of low height.

The inspector must make sure that the tile conforms fully to the specifications in kind, type, quality, size, surface finish, color, and texture; that the glaze is uniform over the entire face and around the edges of the face and does not show evidence of incipient popping or crazing; and that the tiles used are free from all defects that adversely affect their durability or appearance. A semiglazed matte finish is usually prescribed. Frequently tile used must conform to approved samples. In such cases the inspector must compare the tiles delivered with the approved sample and make sure that they conform to it within permissible tolerances in characteristics. Mortar made of white sand and white nonstaining cement usually will be required. The inspector must be sure that the mortar conforms to the special requirements for cement, sand, mix, color, and consistency when used.

In regards to installation, the inspector must assure that block or tile backings for partitions surfaced with glazed tile are constructed several courses in advance of setting of tile and make sure that tiles are thoroughly bonded to the backing. If both sides of a thin partition are to be finished with glazed tile, tile surfaced and glazed on one side only is used, of two different thicknesses to make up the specified total thickness and provide bond. In thinner partitions a single thickness of tile surfaced on both sides is used. In such cases the inspector must determine whether one face is the more important and should be set true and plane, allowing all irregularities in tile thickness to appear on the other face, or whether tile should be set centrally with irregularities in thickness divided equally between the faces. His superior should be consulted if necessary. Subject to the foregoing exception, the inspector should make sure that all glazed tiles are set visually true with horizontal joints level; vertical joints staggered or patterned as shown or prescribed; and surfaces plumb, plane, and free from apparent irregularities. If tiles vary slightly in color, the inspector should be certain that the various shades are distributed to give a uniformly varying tone without patches of darker or lighter shades. He must determine that all joints are carefully filled and tooled as prescribed. He must also ensure that all exposed surfaces are carefully and thoroughly cleaned with nonabrasive detergent or soap and warm water and are thoroughly rinsed.

WOOD

Wood partitions are used in all frame construction and in many instances of more permanent type. In most cases wood partitions are composed of 2- by 4-inch wood studs with sills and plates of the same material. Studs are doubled at openings, and plates are usually doubled to provide strong splices. Headers are required at heads of doors and at heads and sills of sash. Wood partitions to be finished on both sides are covered with wood lath, metal lath, plaster board, or other base, or may be covered in dry-wall construction with wall boards of various types. Wood partitions in offices are frequently of panel construction with studs spaced fairly widely apart and tongue-and-groove panels, wall board, masonite, or other material set in between the studs so the latter are exposed with equal reveal on both faces. Such partitions frequently extend only part way to the ceiling, and upper panels may be glazed. In the tropics, partitions may be surfaced on one side only, leaving the studding fully exposed on the other side to eliminate all concealed spaces and permit effective control of termites and other vermin.

The inspector must be sure that lumber is of the kind, grade, and size specified. If studding is to be exposed, he must be sure that all studs are free from bend, warp, or twist. He must determine that all panels and trim are well manufactured in accordance with the details shown and that surface covering is of the type and quality specified.

The inspector must be sure that all partitions are adequately anchored to the floor, walls, and ceiling as prescribed and, if of part height, are adequately braced and stiffened at all splices and corners. He must be sure that studs are set truly plumb and in line, well nailed to sills and plates, and that plaster base or other surfacing or panels and trim are carefully and accurately installed so that a neat, workmanlike finish is obtained. When necessary, he must make sure that all fastenings are completely concealed behind the trim and that the latter is nailed with finishing brads.

FINISHES

The inspection of finishes for floors, walls and partitions, and ceilings is an important phase of the inspector's job. Ensure that each finishing job is properly done and gives a neat, attractive appearance.

FLOORS

Various types of finishes are used for floors. Here we will cover three of the main types: concrete, wood, and tile.

Concrete

Concrete floor finishes may be either integral with or placed separately from the structural slab and may have coloring pigment or hardening agents incorporated. They usually are specified to be in accordance with NavFac Specification 13Y. The inspector must be sure that materials and workmanship conform to the requirements specified therein for the type prescribed in the project specifications. He must make sure that color pigment or integral hardener is added in accordance with the specifications or approved manufacturer's instructions.

If the finish is to be placed integrally, he must make sure that it is applied within the prescribed time limit and to this end must ascertain that the number of qualified finishers is adequate to keep pace with the rate of placing of the floor slab or that this rate is decreased.

If separate finish is prescribed, he must make sure that the surface of the slab is well roughened, thoroughly cleaned of all loose material, and brushed with neat cement grout immediately before the finish is placed. He must be sure that the finishing concrete is placed at the driest practicable consistency to minimize shrinkage; that dusting on of cement to absorb excess water is not permitted; and that the surface is floated to a true even surface, level or slightly pitched as specified, and is troweled smooth without voids, exposed aggregate, or other visual defects. He must be sure, however, that troweling is not continued to excess, as checking, crazing, and excessive dusting of the finished floor may be caused.

The inspector must assure that the surface is cured as prescribed and for the time specified. He must also ensure that surface-hardening treatments, if prescribed, are applied after the surface is thoroughly cured, using approved chemicals of the type and in the amounts prescribed.

Wood

High-grade wood flooring is generally of oak. Maple is used for special applications, such as mold lofts or dance floors, for which a tight-grained, nonsplintering hardwood finish is required. Southern yellow pine, Douglas fir, and similar softwoods are used for wood flooring of lower grade. Flooring may be rift or edge grain or flat grain and is usually specified to be side and end matched. Wood flooring is also available in parquet or block form of solid or laminated section for cementing in place on structural floors, usually over cork or fiber insulating board.

The inspector must be sure that the flooring has been factory inspected or grade marked, or is of the kind, type, grain, grade, and manufacture specified.

The inspector must be sure that the subfloor, if any has been laid, is truly and fully supported at all points, nailed securely, and covered with building paper if prescribed. He must be certain that the flooring is laid with straight joints, that butts are staggered as prescribed, and that strips are driven tight and blind nailed. If finished flooring is laid directly on joists without subfloor, he should determine that butts are located over supports. He must assure that a minimum of very short lengths are used. If wood flooring blocks are used, he must make certain that the structural floor is absolutely level, or is made level by mastic or other means as may be prescribed; that the insulation prescribed is applied with tight joints and is thoroughly cemented to the deck; and that flooring blocks are laid in true alignment and pattern, driven up tight, and cemented in place with the specified mastic or other cementing agent.

The inspector must determine that flooring is finished by planing, coarse and fine sanding, application of liquid or paste wood filler, and treating with wax, shellac, or varnish, or combinations thereof as may be specified.

Tile

Floor tiles are of several varieties, such as flint tile, unglazed or semiglazed ceramic tile, or quarry tile. Glazed ceramic tile, such as is generally used for wall finish, is occasionally used. Flint and ceramic tiles are usually of small size and of hexagonal, square, or rectangular shape and are delivered assembled in patterns in panels about 12 inches square, cemented on the face to paper. These tiles are also available in various square and rectangular sizes and in a variety of colors, shades, and textures.

The inspector must assure that tiles for both field and borders are of the kind, size, color, texture, and pattern prescribed, and that adequate quantities are on hand to assure completion of each room or area. He must determine that mortar for beds and wire mesh or other reinforcement, if required, conform to the specifications.

The inspector must be sure that the structural floor is prepared ready to receive the tile and to assure a true, level, finished floor. If the floor is of wood, he must make certain that floor joists are leveled at the top and that the subfloor is set down as necessary to provide an adequate mortar bed. If the floor slab is of concrete, he must make sure that it is depressed below finished floor grade as required, roughened to provide bond, thoroughly cleaned, and wet down immediately before the mortar bed is placed. He must be sure that the mortar bed is placed and screeded and that tiles are set immediately and tamped level and true with straight, even, uniform joints. He must assure that tile placed as paperbacked panels is set so that the pattern repeats truly and so that joints between panels match those established within the panels. He must be particularly careful to determine that tile is laid parallel to the principal walls and that all special work required to fill in corners and irregular areas is placed so that joints are true and the pattern is faithfully reproduced without offset or other error. He must be sure that all joints are carefully and neatly filled with mortar as specified and that the floor is cleaned of all mortar. After the mortar has set, he should check the floor for loose tile, irregularities, or other defects and require their correction. Quarry tile may be specified to be set in bituminous mastic or in colored white cement mortar. The inspector must determine that the mortar conforms to the specified requirements and that tiles are set level with even joints and are solidly embedded.

WALLS AND PARTITIONS

Various types of materials are used as finishes for walls and partitions. With space being limited, we will take up only two types here; they are dry-wall construction and tile.

Dry-Wall Construction

Dry-wall construction has been developed as an economical finish for walls, because of the increased cost of plasterwork and relative scarcity of expert plasterers. Essentially it consists of panels of wallboard of various types with joints tight, true, and effectively concealed. The inspector must be sure that the studding or other frame on which the wall is to be installed is brought carefully to a plumb true plane, because irregularities cannot be adjusted as in plasterwork. He must ascertain that all materials used are strictly in accordance with the specifications; that the wallboard is applied accurately, usually in panels extending from floor to ceiling without a horizontal joint, and firmly fastened in the prescribed manner; that vertical joints are plumb, tight, and taped, or otherwise concealed as specified; that the wall is coated with the required number coats of heavy-bodied special paints or spackle as prescribed; and that the finished wall is true and uniform in texture and appearance with joints substantially invisible.

Tile

Glazed ceramic file, glazed vitrified clay tile, and plastic tile are used for wall finishes for baths, galleys, messhalls, hospital rooms, and other applications for which a highly sanitary, easily cleaned, impervious wall finish is required. Tiles are furnished with various types of grooves, ridges, or clincher button heads on the back to assure bond.

The inspector must make sure that the tile furnished conforms to the specifications in kind, quality, size, color, glaze, texture, and grip and that all necessary specials, such as base, corners, decorative band, fixtures, and trim, are of true matching color or of the color or pattern prescribed. He must be sure that the mortar scratch coat is applied and allowed to dry as specified and is ready in all respects to receive the tile; that the mortar bed for tile is applied in the requisite thickness and made true; that the tile is applied and tapped to true plumb alignment with all joints straight, plumb, or level and of uniform thickness; and that the color schemes and patterns are faithfully followed and correctly executed. He must determine that tile is neatly arranged and cut around fixtures; that wainscotting is extended to the prescribed height; that bases align correctly with the finished floor; that joints are filled with plaster of Paris, Keene's cement, or other mortar as prescribed; and that on completion all tile walls are cleaned thoroughly without scratching the glazed surface.

CEILINGS

In view of space limitations, our discussion below on finishes for ceilings will also be held to two materials; they are acoustical tile and acoustical plaster.

Acoustical Tile

Acoustical tiles are available in various materials, such as wood, vegetable, or mineral fiber, perforated metal, or cemented shavings in different thicknesses, shapes, and dimensions and with varying texture, perforations, and joint treatment. They may be nailed, clipped, or stuck in place with the proper adhesive, depending on the ceiling construction.

The inspector must make sure that the tile, hardware for fastening, and adhesive conform to the project specifications or the standard specifications referenced therein. He must make sure that tiles are handled and stored carefully and are not allowed to get wet or even damp, and that all marred, broken, or damaged tiles are culled and not used.

If the file is installed on suspended ceilings, the inspector must make certain that the furring construction is strong, rigid, and in accordance with the specifications. If wood furring is prescribed, he must be sure that the furring strips are spaced accurately to suit the tile width and that tiles are fastened to them by blend nailing or screwing or by countersunk nailing or screwing through the perforations, as may be specified. If metal furring channels are prescribed, he must assure that the tiles are fastened to the channels with approved coupling devices and hangers. When tiles are applied to a finished solid surface, they are cemented with special adhesives, usually with five spots per tile, one near each corner and one in the center, applied to the back of the tiles, which are pressed into place to a true, level plane. The inspector must make certain that all work is accurate and true to plane and line; that all special fitting around pipes, sleeves, and fixtures is neatly done; and that all tiles adhere tightly to the backing material.

Acoustical Plaster

Acoustical plaster is a manufactured product composed usually of asbestos and rock-wool fibers, lime or cement binder, and an aerating agent, factory blended, ready for mixing with water. It is available in white and in light pastel colors.

The inspector must be sure that the material delivered conforms to specification requirements; that it is delivered in sealed, identified containers; that it is mixed with clean water in the prescribed proportions in a clean wood box; that it is thoroughly stirred; and that it is used promptly after it is mixed.

Acoustical plaster is usually applied over a scratch course of gypsum plaster. The inspector must make certain that this coat is applied as prescribed, cross scratched for bond, and allowed to dry thoroughly. He must be sure that the acoustical plaster is applied in the prescribed number of coats to the specified thickness; that the undercoats are each leveled, rodded, and scratched; and that the finish coat is brought to a true level surface of uniform texture with a minimum of troweling to avoid reduction in acoustical qualities. The inspector should make sure that the plaster conforms to any special requirements of the specifications, such as porosity, density, or hardness.

TRIM

There are basically three types of trim: metal, wood, and marble. Marble is very seldom used in the Navy, so we will only discuss metal and wood trim.

METAL TRIM

Metal trim may be of aluminum, brass, copper, bronze, stainless steel, or galvanized iron or steel and may be of either hollow metal or metal-covered wood, called Kalamein.

The inspector must make sure that the trim is of the prescribed kind, grade, quality and thickness of metal; that the dimensions and form of section conform to the details shown; and that the finish is in accordance with the requirements.

The inspector must be certain that all anchors needed are built into the structure in advance and that the fastenings are as detailed, specified, or approved. In many cases special fasteners, such as snaps, clips, or other blend fasteners, will be prescribed. The inspector must be sure that all trim is free from dents, nicks, or other imperfections; that all corners are accurately mitered and welded, brazed, or otherwise joined as prescribed; that all reinforcement for locks, hinge butts, and other hardware is provided, accurately located, and rigidly fastened to the trim; and that the trim is anchored tightly to the supporting members with a snug fit. He must make sure that all trim is protected against damage and that all damage prior to acceptance is made good.

WOOD TRIM

Wood trim or millwork may be of either rare or common varieties of hard or softwood. Regardless of species, millwork usually must be thoroughly seasoned, air dried or kiln dried, and free from knots and sap and must have even straight grain.

The inspector must make sure that the trim has been factory inspected or grade marked or that it is of the species, grade, dimensions, pattern, and finish prescribed; that molded lines are true and sharp without fuzz, flats, or splintered edges; and that the material has been suitably dried and is not warped or curled.

The inspector must make certain that the installation is made with the specified quality of workmanship. On high-grade work he must be sure that all trim is set plumb or vertical with square corners; that all corners are miter cut and coped if necessary for close fit on internal corners and provision is made for expansion and shrinkage; that where long runs are installed in more than one piece, miter cuts and lap splices are used; and that where curved bends are needed, the trim is kerfed on the back so that the cuts are invisible from the front and are close enough together to create a smooth uniform curve without kinks. He must make sure that all trim is nailed securely, that nails or brads are suitable to avoid splitting, and that finishing nails are set adequately but not so deeply as to pull through the wood. He must make sure that all joints and visible seams are sealed with wood filler and that all trim is suitably primed and field painted.

DOORS

An inspection of structures should include both exterior and interior doors. The following sections provide information on some of the different types of doors used at Navy activities. Items that should be checked in an inspection of specific types of doors also are pointed out.

EXTERIOR DOORS

Exterior doors may be of wood, steel, bronze, aluminum, or structural glass. Wood doors may be of hardwood or softwood. Metal doors may be of hollow metal, of structural shapes and plates, or of filled-panel construction.

HINGED DOORS are used for most personnel entrances. They may be single-leaf or double-leaf. Two or more pairs of double-leaf doors may be used for main entrances. Hinged doors may be of wood, hollow metal, filled-panel, or rolled-metal construction. They vary in style from simple stock patterns to highly ornamental designs in bronze, aluminum, Monel metal, or stainless steel. Hinged doors may have exposed or concealed hinges mounted on the jamb or top and bottom set in the head and threshold. Most screen doors are of the hinged type.

The inspector must be sure that hinged doors are of the material, grade, size, type, and design specified and conform to the specifications in all respects. Usually, doors will have been factory inspected. The inspector must determine that they are accurately fitted to the frames with minimum clearance at head, jambs, and sill; that they are weather-stripped, glazed, and fitted with hardware as prescribed; and that they are painted, varnished, or otherwise finished as specified.

Large openings may be closed by HORIZONTAL SLIDING or ROLLING DOORS, usually suspended by hangers from rollers that travel on horizontal or slightly inclined tracks and guided by troughs, grooves, or similar devices at the bottom. These doors vary from simple barn doors to the massive steel-framed doors used for airplane and airship hangers. Doors of this type of large size usually run on wheels mounted in the bottom chord and travel on rails set at grade.

When inspecting horizontal sliding or rolling doors, the inspector must be sure that the doors are plane and free from wind. He must ensure that the doors are mounted so that adequate operating clearance is obtained, but that suitable weathertight closure is also obtained when they are closed. He must make certain that tracks, rollers, roller suspensions, and operators are accurately aligned and adjusted for smooth operation.

Large shop and storehouse openings are frequently closed by STEEL ROLLING DOORS. These doors consist of a large number of interlocking horizontal slats that can be rolled up on a drum mounted above the head of the door opening. The slats are held loosely in channel guides at the jambs. The doors are counter-balanced by a spring tension device for ease of movement and may be operated either by motor or by hand.

In an inspection of steel rolling doors, the inspector must make sure that the slats are true and undamaged and interlock with adjacent slats as intended. He must be sure that the slat assembly is mounted truly on the roller or drum and is correctly fastened so that the slats roll up smoothly and evenly, maintaining their horizontal position. He must make certain that slat ends are provided with guide castings as prescribed or approved, and that these guide castings fit accurately into the side guides with sufficient depth of bearing to assure against their pulling out and with sufficient clearance to assure easy operation. He must assure that the spring counter balance or other balancing device is tensioned for the prescribed ratio of the total load and maintains satisfactory tension throughout the operating range. He must determine that operating machinery is suitably aligned and adjusted, and that all accessories specified are provided and installed.

Alternatively, large shop and storehouse openings may be closed by LIFT DOORS. There are many different forms of such doors. The entire door may be arranged to be lifted vertically in one piece inside the exterior wall. If headroom is limited, vertical lift doors may be subdivided into two or more panels. Each panel is set farther in from the face of the building than the panel above it, sufficiently to provide clearance. The operating devices are designed so that the various panels travel simultaneously past one another at different speeds and reach a common level clear of the opening when they are fully opened. Overhead doors may travel upward and inward so that they reach a horizontal position overhead when opened. Such doors may be in one piece with the motion controlled by two sets of wheels traveling in independent curved guides, may be in several panels traveling in tandom, or may be in panels that telescope and next in the overhead position. These doors usually are counterbalanced and may be operated by hand or motor.

The inspector must be sure that lift doors are installed accurately; that the operating cables or chains are correctly reeved and adjusted so that the doors operate truly without jamming or skewing; that the doors are counterbalanced as prescribed; and that operating machinery is installed, aligned, and adjusted so as to assure easy, trouble-free operation.

INTERIOR DOORS

Interior doors usually are of wood, hollow metal, or metal-covered wood. Plywood or pressed metal may be used for cabinet doors. Hollow metal doors may be filled with sound-absorbing linings. Doors will be factory inspected. Metal-covered wood doors for use as fire doors may be specified to bear the underwriter's label.

Most interior doors are of the single-leaf HINGED TYPE. Double swing doors will be prescribed for some locations.

SLIDING DOORS may be prescribed for closets and for large openings between rooms. They usually will be arranged to slide into concealed recesses when opened. Fire doors are frequently arranged to slide or roll down an inclined track automatically when released by the melting of a fusible link in the anchoring device.

Doors of numerous special types will be encountered, such as elevator doors, trap doors, Dutch doors, lattice and louver doors, incinerator doors, vault doors, and accordion doors.

The inspector must be sure that all doors conform to requirements and are free from any defects that impair their strength, durability, or appearance. He must determine that all doors are of the prescribed types, that doors and door hardware are installed correctly and accurately, and that doors operate freely and close tightly. He must be sure that sufficient clearance is provided above the finished floor to accommodate floor coverings when necessary. He must also ensure that the swing of the doors is in accord with drawings and schedules.

WINDOWS AND SKYLIGHTS

Special care is needed in the inspection of windows and skylights. Check points to be covered in their inspection, including pointers on the inspection of glazing, are given below.

WINDOWS

WOOD WINDOWS usually are of the double-hung or casement types. The inspector must be sure that panels and sash are of the prescribed species and grade of wood, that they conform to the requirements for each type scheduled, and that they are carefully handled and fully protected against damage. He must be sure that frames are carefully installed plumb and square, that sashes are fitted neatly so that they operate freely but without rattling, that sash weights or spring balances are installed and adjusted correctly, and that all hardware and weatherstripping specified are installed and adjusted satisfactorily. He must determine that casement sashes are hinged to swing in or out as shown, that they fit accurately and are suitably weatherstripped, and that operators, bolts, and other hardware are accurately positioned and adjusted.

STEEL AND IRON WINDOWS are available in many types. Among the more common are double-hung, pivoted, commercial projected, architectural-projected, casement, top-hinged, continuous, and detention or security types. The inspector must be sure that the windows are of the prescribed type, size, grade, and section of members and conform to the specifications in details and workmanship, and also that the windows installed in each opening conform to the schedule shown or specified. He must make certain that windows are carefully handled and stored, and are free from distortion when they are installed. He must be sure that all anchors, bolts, and clips needed for fastening the windows in place are installed; that frames are set accurately and truly and are calked as prescribed; that ventilators are set accurately and adjusted so that they operate freely and close tightly; and that all operators and other moving parts are made to operate smoothly and easily without strain.

Most ALUMINUM WINDOWS are built of extruded shapes of relatively light section. They are available in most of the types listed for steel windows in the preceding paragraph but are generally of the double-hung or casement types. Requirements for inspection are substantially the same as for steel windows. The inspector must be sure that aluminum is of the grade and temper prescribed. Usually the manufacturers caution that windows must be kept locked and not opened until they are set and glazed. The inspector should insist that this practice is followed. He must determine that care is taken to avoid marring the members during installation, because of their relative softness.

SKYLIGHTS

Skylights of the framed type may be constructed of galvanized iron, asbestos-protected metal, copper, aluminum, stainless steel, or Monel metal. The inspector must be sure that the skylights conform to the details shown; that all necessary steel supports, base curb, and reinforcement are provided; that skylights are flashed to all adjoining work in a watertight manner; that bars are provided with suitable shoulders for the support of the glass and with gutters for the collection of condensation; that glass is set on felt or in putty as prescribed; and that caps are set and adjusted so as to be watertight without imposing restraint or strain on the glass.

Skylights may be provided by installing corrugated glass in panels on roofs of corrugated types. The inspector must be sure that glass is of the type, thickness, and size prescribed. He must make certain that the glass is fastened securely, but without restraint or strain, and that the installation is made completely watertight.

GLAZING

Glass may be clear window, polished plate, processed, rolled figured sheet, figured plate, wire, prism, corrugated, safety, or heat-absorbing glass.

The inspector must make sure that the glass for each location is of the type, grade, thickness, surface finish, color, and size prescribed and conforms to all requirements of the project specification or referenced standard specification. He must determine that putty is of the type and quality specified and that all points, clips, and other devices conform to requirements. He must be sure that all glass is carefully handled, stored, and protected from damage.

The inspector must assure that all glazing is correctly done; that glass is held in wood with zinc glazier's points and in metal with approved spring clips; that glass is neatly bedded in putty or back-puttied as prescribed; that glass is set with uniform bearing and without strain; and that stops or beads are installed where prescribed. He must be sure that all figured glass is set with the correct face out. He must make certain that all strains, labels, and excess putty are removed; all broken glass replaced; and all glass cleaned and polished as prescribed.

PAINTING

An inspector needs to possess a thorough knowledge of paint materials, equipment, and painting procedures. He must also be able to inspect both exterior and interior paint jobs involving different types of surfaces.

STEEL STRUCTURES

Thorough preparation of the surfaces to be painted is the most important and most frequently slighted element of good painting. It is of particular importance if paints with synthetic resin vehicles are to be used, because they require exceptionally clean, dry surfaces for satisfactory results. The inspector must be sure that steel surfaces are cleaned by wire brushing, sandblasting, gritblasting, flame cleaning, cleaning with solvent, or airblasting, as may be specified; that all surface rust, dirt, grease, oil, and loose scale are removed; and that tight scale is also removed, if so specified. If the use of chemical rust removers is prescribed or permitted, he must make sure that the preparation is of an approved type and is brushed on thoroughly and allowed to dry, and that all loose material is brushed off. Galvanized surfaces must be treated with diluted muriatic, phosphoric, or acetic acid, rinsed, and allowed to dry, or treated with approved proprietary treating agents as may be specified.

The inspector must be sure that ready-mixed paint, which tends to settle in the container, is thoroughly remixed to uniform consistency by hand or power stirring. Usually it is necessary to pour off the lighter fluid into another clean container, stir the heavier residue until it is uniform, and then add the lighter liquid gradually, with continuous stirring, until the paint has been worked to a smooth, even, homogeneous mixture. The inspector must make sure that paints delivered with pigments and vehicles in separate containers are similarly mixed, preferably with power stirrers. Color usually is furnished as color-in-oil and in paste or liquid form. The inspector must make certain that color is added in the correct quantities to assure a uniform tint for each field coat and that, when specified, the quantities for successive coats are varied to distinguish the coats and facilitate inspection. The inspector must make sure that thinning is permitted only when specifically authorized and that the amount of thinner added is limited to the minimum required for satisfactory application.

The inspector must be certain that paint is applied only under satisfactory atmospheric conditions. The specifications usually will prescribe the minimum temperatures at which painting may be done. The inspector must assure that paint is not applied in a highly humid or rainy atmosphere, or when condensation on the metal surface may occur. He must be sure that the paint surface is visually dry before permitting painting to proceed. Specifications may prescribe application by brush or spray or permit either method. If paint is applied by brush, the inspector must be sure that each coat is thoroughly worked with suitable brushes until a smooth, even coat is obtained, free from brush marks, laps, holidays and drips of excess paint. He must ascertain that paint is worked thoroughly into all joints, cracks, and crevices. He should check the coverage obtained and verify that the area covered per gallon is within acceptable limits. He must make certain that each coat is allowed to dry thoroughly before the next coat is applied, and that the prescribed number of coats, each conforming to the requirements of the specifications, is applied.

EXTERIOR PAINTING

The inspection of exterior paint jobs will involve woodwork, metalwork, and concretework. The inspector must know what to look for in inspecting each type of surface.

Woodwork

The inspector must make sure that surfaces are thoroughly dry and clean and are otherwise suitably prepared for painting before permitting work to proceed. He must determine that the priming coat is intact and of suitable consistency to protect the wood, but not so tight that moisture in the wood is prevented from evaporating. For exterior work, sandpapering will not be prescribed. The inspector must be sure, however, that the wood is smooth enough to assure the continuity and adherence of the paint film. He must make sure that holes and cracks are puttied or filled with wood filler, and that knots and pitch streaks are sealed with shellac, varnish, or other sealer as prescribed.

The inspector must be certain that paints are of the prescribed type and quality; are mixed, colored, and thinned to provide a paint of uniform consistency and color; and are applied by brushing, using high-quality brushes, until the coat is smooth, even, free from brush marks, and of uniform thickness, texture, and color. He must be sure that all cracks and crevices are sealed and that the paint is not brushed too thin to assure satisfactory hiding power. He must make certain that each coat is allowed to dry thoroughly to a firm film before permitting application of the next coat and make sure that the specified number of coats is applied. Staining of shingles and trim may be performed by dipping or brushing. The inspector must be sure that in dipping, the material is loosened so that the stain reaches all immersed surfaces and is left immersed until stain has fully penetrated the grain; that excess stain is drained off; and that stain is replenished and stirred to assure uniformity.

Metalwork

Requirements for inspection of painting of exposed ferrous metalwork have been described in the section entitled "Steel Structures." Nonferrous metalwork usually is not painted. When painting is prescribed, the inspector must be sure that surfaces are prepared, primed, and painted as specified. Inspection procedures as described earlier for steel structures are generally applicable.

Concretework

Painting of concrete, stucco, and similar surfaces is done primarily for decorative purposes or for dampproofing walls. Paints usually are of white portland cement base with color, but may be of oil base. The inspector must be sure that the materials conform to the project specification or the applicable referenced standard specifications. He must determine that surfaces are clean and free from dust, effloresecence, and other contamination and are adequately cured. If portland cement paint is to be used, he must be certain that the surface is thoroughly wetted. If oil-base paint is to be used, he must assure that the surface is thoroughly cured, pretreated as prescribed, and thoroughly dry. Inspection of application should conform generally to the instructions for inspecting painting of exterior woodwork.

INTERIOR PAINTING

Paint for interior WALLS AND CEILINGS usually will be a flat wall paint. For small jobs the specifications may permit the use of approved commercial ready-mixed paints. Interior enamel may be prescribed where a semigloss or gloss washable finish is desired on woodwork or walls. The specifications may prescribe a standard undercoat for primer under enamel, or may permit the use of the enamel with thinner. Paint and enamel may be obtained with color added, or color-in-oil may be added to the white paint on the job.

Requirements for inspection of interior painting are in general the same as those described above for exterior painting. Specifications may require sanding of interior woodwork or rubbing with steel wool and may require priming of plaster surfaces with a glue size. The inspector must be sure that finish coats are of uniform gloss and color and are free from suction spots, highlights, brush marks, and other imperfections. The inspector should note that color in most interior paints lightens appreciably in tint when dry and tends to fade, while color in exterior paints tends to darken after continued exposure. Staining and varnishing may be prescribed for hardwood trim and millwork.

New WOOD FLOORS are seldom painted or stained. Usually, hardwood floors will be given a floor coat, one or two coats of floor sealer, and a polished wax finish. Varnish or shellac may be prescribed for floors of emergency or temporary structures. The inspector must be certain that all materials conform to the specified requirements.

The inspector must be sure that wood floors are machine sanded to a uniform level surface and that all sand and dust are completely removed. He must determine that paste wood filler, thinned with turpentine or mineral spirits if necessary, is brushed thoroughly into the surface; that the excess is removed by scrubbing with burlap; and that the filler is allowed to dry thoroughly. He must be certain that floor sealer, if prescribed, is applied liberally in one or two coats as specified; that all excess sealer is removed; and that the surface is buffed and burnished, if required, and allowed to dry and harden thoroughly. If wax polish is prescribed, he must assure that the wax is applied in paste or liquid form as specified or permitted, spread uniformly and thinly, and polished with a power-driven polishing machine. He must make sure that areas inaccessible to the machine are rubbed by hand. Asphalt tile and rubber tile may be required to be waxed. Inspection procedures should be the same as for wood floors.

SPECIAL WORK

ALUMINUM windows, doors, and trim usually will not be painted, but will be given an alumilite or other anodic surface treatment at the factory. When painting is specified, it will be necessary to clean the surface thoroughly, so that it is free from all dust, dirt, oil, and grease; apply a primer of the type prescribed; and apply one or more field coats of paint as prescribed.

Where dissmimilar metals are in contact, ELECTROLYSIS may occur that causes the rapid corrosion of the anodic or positively charged material. Magnesium, zinc, and aluminum corrode when in contact with steel; steel and iron corrode when in contact with copper, brass, or bronze; and copper and its alloy corrode when in contact with the precious metals. Zinc coating protects steel at the expense of the zinc coating. The inspector must be sure that aluminum is well isolated from steel and steel from copper by felt, varnish, or other method as specified. Cathodic protection by impressed current is another method of resisting galvanic action.

Metal work exposed to continued or periodic immersion in water is frequently protected by COAL-TAR ENAMEL. It is imperative that such materials be applied in strict accordance with specifications. The inspector must make sure that the entire surface is thoroughly clean and dry and that atmospheric conditions are such that condensation cannot occur. Temporary dehumidification may be necessary. The inspector must assure that coal-tar primer is of the specified grade and is applied at suitable temperature and that complete coverage is obtained. He must determine that coat-tar enamel is flowed or mopped on to the prescribed thickness and is free from holidays. Special care must be taken to make sure that edges of structural members are fully protected. If prescribed, the coating must be tested by a flaw detector or approved type.

COAL-TAR or ASPHALT paint may be prescribed for the protection of smokestacks, breechings, and other installations where coal-tar enamel would not be suitable. These paints vary considerably in type, composition, and characteristics. The inspector must make certain that the material conforms to the specifications and is applied so as to provide a coating of the prescribed thickness, free from flaws and holidays.

Before paint can be applied successfully to bright GALVANIZED METAL, the surface film must be removed and adequate tooth provided by treating the surface with dilute hydrochloric, phosphoric, or acetic acid. A 5-percent solution usually is prescribed. The inspector must determine that the surface is completely treated and is then rinsed thoroughly with clean water. A small amount of lime sometimes is added to neutralize any residual acid. When dry, surfaces so treated are primed and painted like other metal work.

CHAPTER 10

CONSTRUCTION INSPECTION: ADDITIONAL STRUCTURES

In the preceding chapter you learned various items to be checked in inspecting the construction of buildings and other such structures. The subject of inspections is continued in this chapter. We will discuss inspection requirements applicable to pile, concrete, and timber construction, in which case various types of structures may be concerned. Inspection of piles, for instance, may involve waterfront structures, as well as foundations of buildings and other structures on land where piles are used. We will also discuss check points to be covered in inspecting specific types of structures, such as bridges, cofferdams, and wharves. A thorough understanding of the material in these two chapters should give you an idea of the important role of the inspector in inspecting structures involving light, heavy, and concrete construction. Bear in mind that here, as in the preceding chapter, we are concerned with inspections of new construction, rather than with maintenance inspections of existing structures. Information on maintenance inspections of existing structures is presented in chapter 11.

PILE CONSTRUCTION

The inspection of pile driving is an extremely important phase of an inspector's duties. There is probably no other type of construction work that requires quick, sound decisions to be made on the spot as frequently. Every inspector assigned to supervision of pile-driving operations should familiarize himself thoroughly with all details of the materials, equipment, and techniques used in pile driving and of the application and limitations of the methods of evaluating safe bearing capacity.

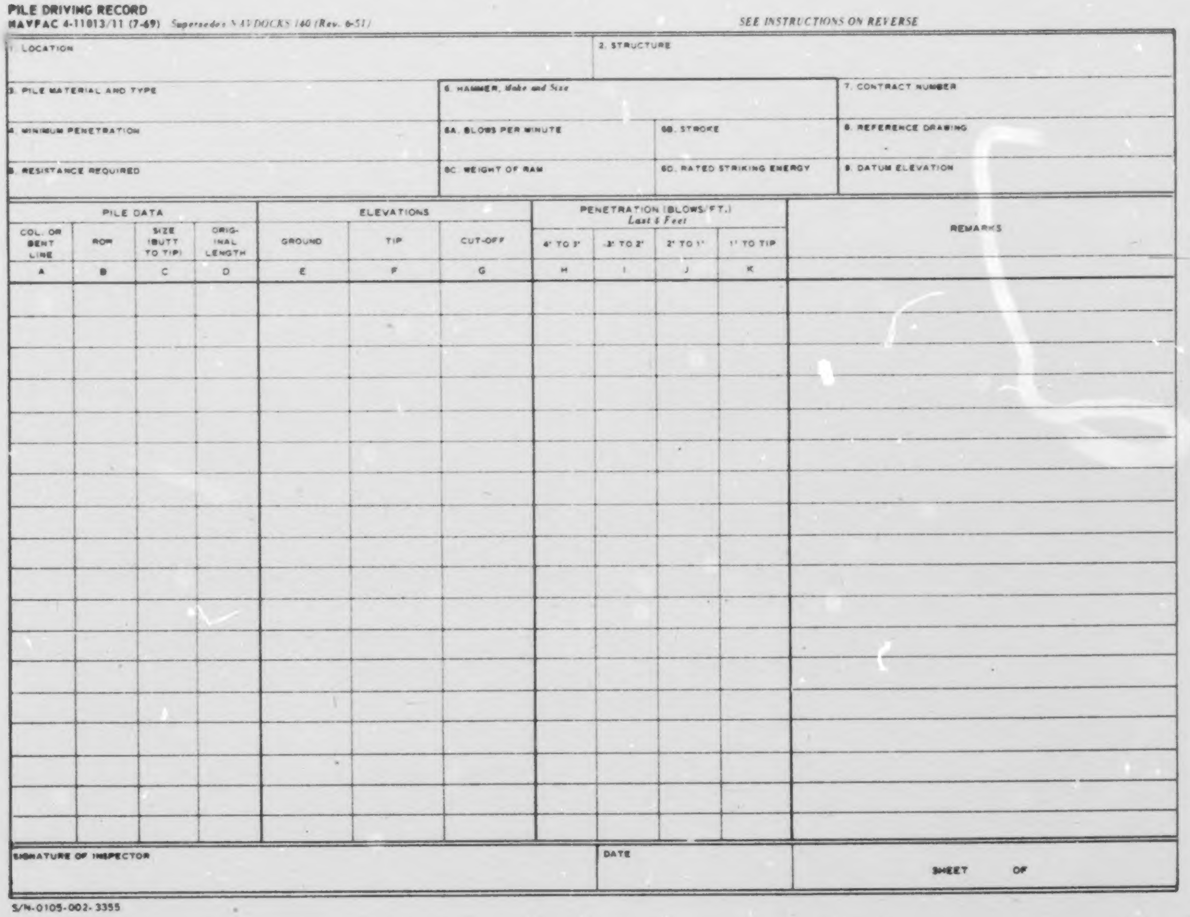
PILE DRIVING

The accuracy with which piles must be located varies with the character of the work. Extreme accuracy in positioning is not essential, for example, in a large mat foundation supported on piles at relatively wide centers. It is important in closely spaced footing clusters, and particularly important in such cases as bridge bent piers, in which the upper part of the pile is exposed and any misalignment is immediately noticeable and objectionable. The inspector must make sure that piles are positioned with the accuracy required by the circumstances, but he should avoid arbitrary and unduly burdensome requirements when they are not reasonable. When close tolerances are essential, the specifications may require the use of templates to assure proper centering. In such cases, the inspector must make sure that the templates provided are strong enough to withstand the abuse to which they are subjected, and that they are maintained square and rigid.

Care must be taken to see that the pile is handled without undue strain or shock, that the pile is set plumb in the leads, and that the pile-driver leads are themselves plumb. Special attention must be given to the rigging used for lifting precast concrete piles, to prevent overstraining and cracking the piles. It is difficult to reposition a pile that has been started slightly out of position; and it is almost impossible to straighten up a pile that has been started crooked.

The inspector must be present during the driving of every pile incorporated into the permanent structure and must keep a detailed record of the driving on the "Pile Driving Record," NAVFAC Form 4-11013/11 shown in figure 10-1. It is imperative that all items on the form be filled out completely and accurately in accordance with the instructions which are given on the reverse side. (See fig. 10-2).

The inspector must make sure that the hammer used is heavy enough to be effective, considering the weight of the pile. The hammer should weigh as much as the pile being driven and preferably up to twice the weight of the pile. Hammers that are too light waste their energy in impact and inertia effects. In driving the piles down, force is so little that its effectiveness causes gross erroneous indications of bearing capacity, far above what the pile will actually sustain. The hammer must strike the pile squarely, or additional energy will be lost in springing the pile sideways. If batter piles are being driven, the inspector must make sure that the leads are set for the proper batter and that the piles are held true to top position and batter as they are driven. If timber piles are being driven, the inspector must make sure that protective rings of proper size are used at the heads of the piles to protect them from splitting, and that pile shoes of approved design are used and properly secured when called for or required.



PILE DRIVING RECORD
NAVFAC 4-11013/11 (7-69) *Supersedes NAVDOCKS 140 (Rev. 6-51)*

SEE INSTRUCTIONS ON REVERSE

1. LOCATION
2. STRUCTURE
3. PILE MATERIAL AND TYPE
4. MINIMUM PENETRATION
5. RESISTANCE REQUIRED
6. HAMMER, *Make and Size*
6A. BLOWS PER MINUTE
6B. STROKE
6C. WEIGHT OF RAM
6D. RATED STRIKING ENERGY
7. CONTRACT NUMBER
8. REFERENCE DRAWING
9. DATUM ELEVATION

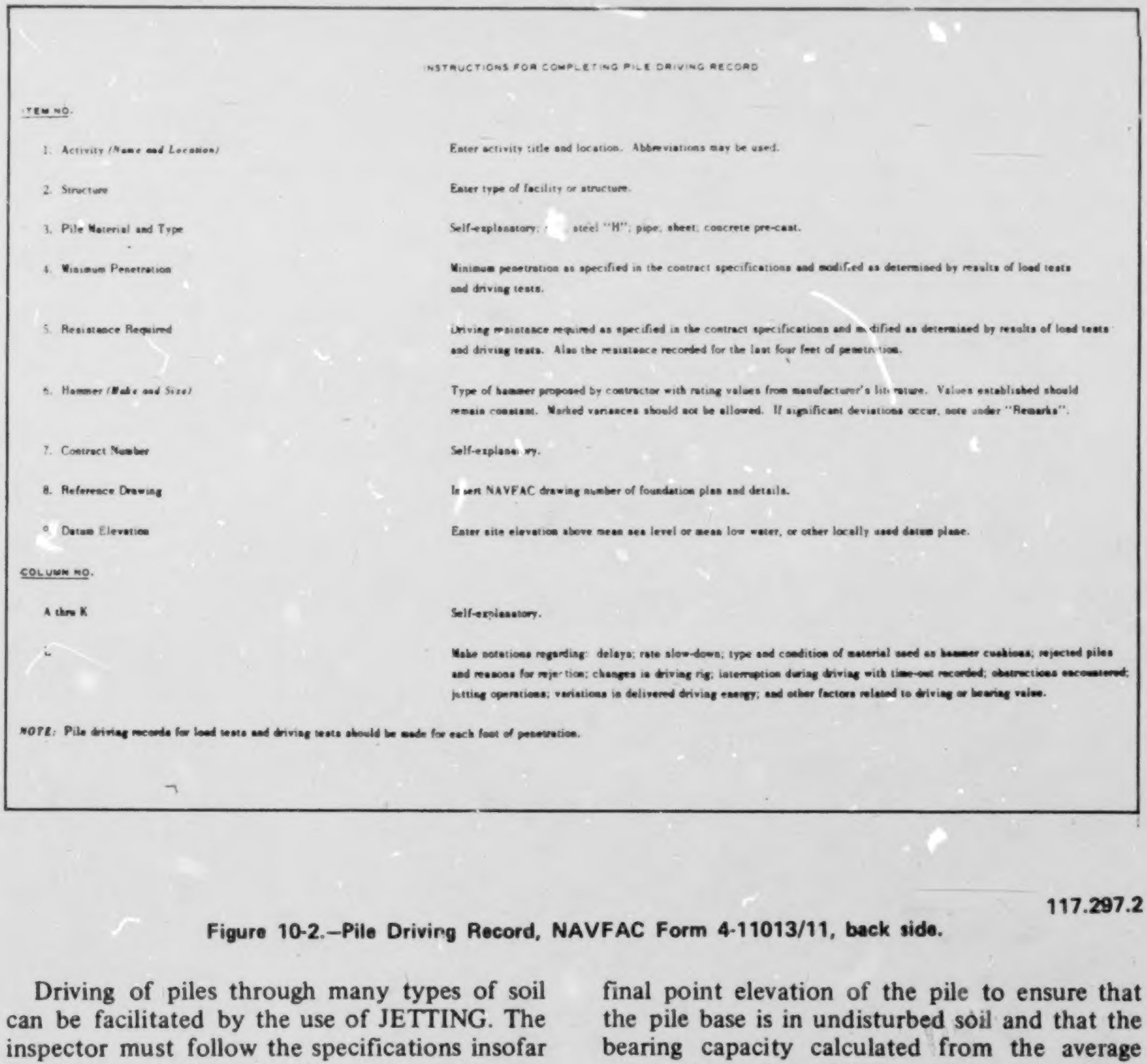
PILE DATA				ELEVATIONS			PENETRATION (BLOWS/FT.) *Last 4 Feet*				REMARKS
COL. OR BENT LINE	ROW	SIZE (BUTT TO TIP)	ORIGINAL LENGTH	GROUND	TIP	CUT-OFF	4' TO 3'	3' TO 2'	2' TO 1'	1' TO TIP	
A	B	C	D	E	F	G	H	I	J	K	

SIGNATURE OF INSPECTOR
DATE
SHEET OF

S/N-0105-002-3355

117.297.1

Figure 10-1.—Pile Driving Record, NAVFAC Form 4-11013/11, front side.



INSTRUCTIONS FOR COMPLETING PILE DRIVING RECORD

ITEM NO.	
1. Activity *(Name and Location)*	Enter activity title and location. Abbreviations may be used.
2. Structure	Enter type of facility or structure.
3. Pile Material and Type	Self-explanatory; [illegible] steel "H"; pipe; sheet; concrete pre-cast.
4. Minimum Penetration	Minimum penetration as specified in the contract specifications and modified as determined by results of load tests and driving tests.
5. Resistance Required	Driving resistance required as specified in the contract specifications and modified as determined by results of load tests and driving tests. Also the resistance recorded for the last four feet of penetration.
6. Hammer *(Make and Size)*	Type of hammer proposed by contractor with rating values from manufacturer's literature. Values established should remain constant. Marked variances should not be allowed. If significant deviations occur, note under "Remarks".
7. Contract Number	Self-explanatory.
8. Reference Drawing	Insert NAVFAC drawing number of foundation plan and details.
9. Datum Elevation	Enter site elevation above mean sea level or mean low water, or other locally used datum plane.
COLUMN NO.	
A thru K	Self-explanatory.
L	Make notations regarding: delays; rate slow-down; type and condition of material used as hammer cushions; rejected piles and reasons for rejection; changes in driving rig; interruption during driving with time-out recorded; obstructions encountered; jetting operations; variations in delivered driving energy; and other factors related to driving or bearing value.

NOTE: Pile driving records for load tests and driving tests should be made for each foot of penetration.

117.297.2

Figure 10-2.–Pile Driving Record, NAVFAC Form 4-11013/11, back side.

Driving of piles through many types of soil can be facilitated by the use of JETTING. The inspector must follow the specifications insofar as they prescribe specific requirements for jetting. Usually, jetting is done by one or more pipes with nozzles hung from the driver and operated independently of the pile. Some precast concrete piles have been used with the jet pipes cast in the piles. Such cast-in jets cannot be moved around as needed to obtain best effectiveness, and their use has been largely discontinued. The inspector should permit the widest latitude possible regarding methods of jetting. However, he must make sure that jetting is discontinued a sufficient distance above the final point elevation of the pile to ensure that the pile base is in undisturbed soil and that the bearing capacity calculated from the average penetration of the last few blows is a reliable index.

The inspector must make sure that piles are driven to the minimum point elevation specified, or to the minimum penetration below the ground, bottom of footing, or mud line, as may be specified. If neither point elevation nor minimum penetration is shown or specified, the inspector should make sure that the driving is continued until the penetration per blow is reduced to the limit indicated by the formula for the required bearing capacity. If jetting is permitted, the inspector must make sure that the driving is continued into undisturbed material. If the required bearing capacity is obtained with very short piles, the inspector should report the situation to his superior promptly and request further instructions.

Requirements for CUTTING OFF piles vary with the character of the work. The inspector must ascertain the specification requirements governing tolerances of cutoff. Special accuracy is needed when precast caps, stone masonry, or timber caps or grillages are to be set on top of piles. Less accuracy is required when the tops of the piles will project into concrete cast in place around them. In the former case, the inspector must make sure that the necessary accuracy in elevation of cutoff is obtained and that the tops are cut off to a true plane, with the use of a template if necessary.

Cutting off piles under water requires special equipment and an extremely careful technique, particularly in tidal waters or rivers in which the level is variable. When feasible, it is preferable to use a traveling carriage supported on piles to carry the cutoff saw, which is suspended on a vertical shaft, adequately braced. When this is impracticable and it is necessary to use floating equipment, special precautions are necessary to assure accurate cutoff elevation. This is usually done by establishing horizontal range sights on shore and by bringing marks on the saw spud or shaft assembly carefully to this level.

Piles are occasionally designed to resist uplift. In such cases, the pile must project further into the foundation and be notched to provide an upward bearing at a distance below cutoff sufficient to preclude failure in shear above the bearing. The inspector must make sure that the piles are carefully shaped to the required form and that the heads of the piles above the bearing shoulder are sound.

BATTER PILES are usually driven by swinging or pendulum leads pivoted to the fixed pile-driver tower, or by fixed leads held at the proper angle by suspension from a crane, but accurate control of driving is extremely difficult and results usually are hard to achieve. The inspector should satisfy himself that the methods proposed are adequate to assure satisfactory results. He should make sure that the rig provides a true axial impact and that the piles do not spring sideways excessively under the blow. He must make sure that piles are driven to the specified depth or point elevation, making allowance for the slope distance.

When it is necessary to drive timber piles longer than they can be obtained economically as single sticks, two piles may be spliced. Also, an uncreosoted lower section may be joined to a creosoted upper section by splicing when the short length requiring preservative treatment makes it economical to do so. The inspector must make sure that the splice is carefully made in accordance with the drawings and specifications, with abutting faces in full tight contact, with sleeves driven or wedged tight, and with bolts or lag screws made tight and driven in tight holes. The splice is unavoidably a point of weakness, and the fullest care should be taken to make it as rigid as possible.

Steel H or pipe piles can be spliced readily by welding an upper section on the lower one after the latter has been driven nearly to grade. This method is frequently adopted for very long piles to make excessively long leads unnecessary. The inspector must make sure that the sections are aligned axially, that full square bearing is obtained, and that the welding is carefully and properly done. Steel piles are frequently of high-carbon steel to provide resistance to deformation under impact, and therefore special precautions are necessary in welding techniques to assure a satisfactory weld.

Cast-in-place piles are lengthened by adding sections to the shells as required. Precast piles can be lengthened only by building up a pedestal, reinforced as necessary, to compensate for overdriving.

Cast-in-place piles can be driven on top of wood piles by the use of specially designed sleeve joints furnished by the manufacturers of the shells. Precast piles can also be driven on wood-pile lower sections. A sleeve is usually cast onto the point of the precast pile and securely anchored into it. The inspector must make sure that the field connection is true and tight in all respects and conforms to the details shown.

DIFFICULTIES ENCOUNTERED IN PILE DRIVING

Various defects are encountered in working with piles. Some of the common types of defects which the inspector may encounter in wood and concrete piles are discussed below.

Wood Piles

The inspector must be alert to detect and take steps to correct deficiencies in equipment and methods which may damage wood piles. Overdriving or use of too high a fall with drophammers may lead to such defects as brooming, breaking, shearing, twisting, or shattering of the pile. The inspector must learn to recognize the indications of such failures and must require that methods be modified, if necessary. Overdriving is usually indicated by bending or staggering of the hammer. Breaking or shearing is indicated by sudden resumption of easy driving after the pile has apparently been driven to practical refusal. Similar behavior may occur when the pile breaks through a hard crust into a softer stratum. Sudden hard driving may indicate that the pile has struck a boulder. Sudden change of direction may indicate that the pile has sheared or broken, or that the pile has glanced off a boulder. The inspector should inform his superior if such difficulties recur and he is in doubt as to the cause. He should appreciate that damaged piles may endanger the safety of the structures that they support.

Concrete Piles

Common failures which may occur in PRECAST CONCRETE PILES are cracking and spalling or shattering of the head.

Cracking may occur from faulty mixes or curing, but usually occurs from carelessness or improper rigging in handling. Piles should be inspected frequently and minutely during driving to make sure cracks do not exist. They are particularly dangerous in the portion above the mud line, where they may permit corrosion of the reinforcement to occur. If numerous cracks occur, the situation should be reported to your superior so that a full engineering investigation can be made and the causes corrected.

Spalling or shattering of the heads usually occurs in precast concrete piles because the proper followers and driving blocks are not used. The equipment should be modified if these troubles develop consistently. Piles with badly shattered heads cannot be repaired effectively so that they can be driven with assurance that full bearing capacity is obtained. It may, in extreme cases, be necessary to remove and replace the pile. If the pile is not damaged badly enough to warrant rejection, the inspector should require the removal of all unsound concrete and building up to the finished cutoff.

With CAST-IN-PLACE PILES, difficulties are sometimes experienced through tearing of the shells, or partial collapse after the mandrel is removed. A customary emergency measure is to drive a second shell inside the damaged shell. All shells should be inspected by throwing a beam of light down the shaft with a mirror and determining that they are sound, intact, and tight. Piles that are rejected as defective must be filled with concrete to eliminate a hole in the ground that could subsequently decrease the bearing capacity of adjacent piles.

The principal difficulties encountered with STEEL PILES are twisting and distortion of the heads. Special care must be taken to see that caps of proper design to prevent this action are provided.

CONCRETE CONSTRUCTION

All concrete construction must be in accordance with NAVFAC Specification 13Y, except as specifically modified by the project specifications. Inspectors assigned to inspection of concrete construction must have a thorough understanding of the requirements of the standard specifications, of the reasons for these requirements, and of the best techniques and methods for meeting them.

The standard specifications cover a wide range of possible conditions and allow a choice of types of cement, sizes and types of aggregates, and classes of concrete. The specific requirements for each project must, therefore, be set forth in a definitive manner in the drawings and specifications for the work. The inspector should verify that all variables and options permitted by the standard specifications are fixed by the project documents, and should call any apparent omissions to the attention of his superior.

PREPARATORY WORK

As soon as the plant is set up for producing and delivering concrete, the inspector should familiarize himself with the functional arrangement and check all equipment to make sure that it is in good working order and accurately calibrated. He should be present at any trial runs made and make sure that any deficiencies that develop are corrected. If any serious deficiencies are apparent that cannot be readily overcome and that might affect the efficiency of the operations, the inspector should inform his superior of the situation.

Before permitting any concrete to be placed, the inspector must satisfy himself that all excavation has been completed; that banks have been stabilized or protected by bracing, sheeting, or sheet piling as necessary; that excavated areas have been dewatered to assure that working areas can be kept dry; that all dowels, anchors, inserts, and similar devices have been placed properly in all previously constructed work; and that all contact surfaces have been carefully cleaned of all debris and roughened if necessary.

The inspector must make sure that the forms comply in all respects with the applicable requirements of NAVFAC Specification 13Y; are of the materials, surface type, and smoothness specified; are amply strong and properly tied together to withstand the hydrostatic pressure of the wet concrete; are tight against leakage of mortar; are true to line, grade, and shape; and are rigidly supported so that settlement, misalignment, yielding, or spreading will not occur under the weight or thrust of the concrete; and that forming for openings and recesses has been provided in strict accordance with the plans. If old forms are being reused, he must make sure that they have been properly repaired and cleaned. If the forms are of considerable height, he must see that openings have been provided as necessary for placing concrete without excessive drop. Before placing of concrete is started, he must make sure that all debris has been completely removed from inside the forms and that the contact surfaces of the forms have been wetted, oiled, or coated as prescribed. Generally form contact surfaces are oiled prior to erection. When used for footings, abutments, and other large sections the forms may be oiled after erection if care is taken to avoid getting oil on the reinforcement.

All reinforcement must be checked in detail to make sure that it is of the specified size, length, type, form, and spacing; is clean and free from loose rust or scale; is firmly secured by approved devices against displacement; and is accurately located to assure that the required cover will be obtained. Splices must be checked for location, length of lap, and clearances between bars. When welded butt or lap splices are required or permitted, the inspector must check the quality, size, and amount of weld.

The inspector must be sure that all anchors, inserts, dowels, sleeves, pipes, and similar fixtures that have to be embedded in the concrete are accurately placed and firmly secured to the forms. Prior to and during placing operations, the inspector must check the concrete mixture for conformity with specifications. This means verifying slump tests, air-entrainment tests, and the preparation of laboratory test samples for compressive and flexural strength tests.

PLACING

When ready-mixed concrete is to be used, the inspector must make sure that the requirements of NAVFAC Specification 13Y for the method of mixing and delivery are fully met. When job mixing at a central plant at the site is adopted, the inspector must make sure that the methods of transporting the concrete assure rapid delivery without segregation or loss of material.

Concrete may be conveyed from the mixer or delivery point to the forms by carts, buckets, chutes, pneumatic methods, pumping, or tremie. The requirements and limitations or NAVFAC Specification 13Y for the method used must be strictly met. The inspector must make sure that methods and equipment meet with the approval of his superior when so required. He must, in all cases, be satisfied that the concrete as placed is acceptable in all respects, and must require correction of deficiencies in methods or equipment if the concrete is not of acceptable quality.

The inspector must make sure that the concrete is deposited without dropping and without displacing the reinforcement; that, as placed, it is uniform and free from segregation; that it is effectively compacted by spading, vibration, or other specified means; and that all other specification requirements applicable to the project are fully met. He must make sure that construction joints and expansion joints are provided at all required locations and are properly located and formed. If concrete is placed in cold weather, by tremie, or under other special circumstances, he must make sure that the special precautions required are taken.

FINISHING

Because NAVFAC Specification 13Y provides for various types of finishes, the inspector must refer to the project specifications to determine the specific types of finishes to be required. NAVFAC Specification 13Y prescribes clearly the requirements for each type. The inspector must remember the importance of uniformity of finish and surface texture. He should familiarize himself with the proper techniques for achieving satisfactory results and with the causes and methods of avoiding the common defects in finish. Excessive surface water, for example, results from too wet or too sandy a mix, or from overworking. Such excess water should be removed by blotting methods or by evaporation and not by sprinkling dry cement on the surface. Excessive troweling brings laitance to the surface and gives a surface that soon dusts and deteriorates. Too rapid drying leads to hair cracks. Placing a topping over dry concrete causes alligator cracking from rapid absorption of water by the base course. The inspector must assure himself that the methods and techniques used preclude such defects and deficiencies.

CURING

NAVFAC Specification 13Y contains specific requirements for the protection and curing of concrete, including special requirements for certain cases. The inspector must determine which requirements are applicable to the project. He should give careful attention to the requirements for length of curing period required and length of time forms or supports must be kept in place. He must make sure that curing methods are such that the concrete is fully protected against drying out prematurely. If membrane waterproofing is permitted, the inspector must make sure that the membrane seal is applied so that no gaps or holidays occur and must require a second application over uncovered areas.

TIMBER CONSTRUCTION

This section relates primarily to inspection of the field erection of timber structures. Some of the major items to be covered in the inspection are given below.

DELIVERY AND STORAGE

When timber is delivered to the site of the work for incorporation into the structure being constructed, the inspector must make sure that it has been inspected and grade marked as required by the specifications or as approved by proper authority, and that inspection certificates have been furnished by the inspecting agency. He must ensure that these certificates are properly identified as pertaining to the material delivered, and that the tally of material delivered is correct. If it is treated material, the inspector must make sure that the inspection reports of treatment are received, are identified, and indicate that the treatment complies with requirements. If inspection before delivery has been waived for any reason, the inspector must make sure that the timber conforms in species, dimensions, and quality to the requirements of the specifications.

The inspector must make sure that all timber is unloaded with reasonable care so that it is not damaged in handling. He must see that special care is taken in handling timber treated with creosote or other preservatives to preclude damage penetrating the more heavily treated surface layer.

The inspector must require that timber be stored in a well-drained area so that it will be clear of the ground; that it be stacked so that there is good circulation of air through the pile; that in stacking, one end be raised so that water will drain off without standing; and that the layers be adequately supported so that the lower layers will not be crushed by the weight of the material above them. The high end of the stack should preferably be cantilevered forward at the top to provide an eave effect. Kiln-dried timber, finish lumber, and millwork must be stored under cover.

FABRICATION

The inspector must allow latitude on the type and arrangement of plant and equipment to be used on the job, but must make sure that the plant is adequate for the work, is arranged to minimize interference with others or with station operations, and is safe. The scope of the plant will depend both on the magnitude of the work and on the extent of manufacture and prefabrication before erection.

When a large volume of repeat work is involved, all cutting, matching, and shaping, and as much prefabrication as practicable will generally be done at a central woodworking plant at the site prior to erection. This procedure assures more accurate work at considerable saving in labor and is to be encouraged as tending to assure a better job. The inspector should give special attention to checking first runs of each production run to make sure that each piece is cut and shaped to correct dimensions and pattern. When required by the project specifications the inspector must check to see that all fabrication is accomplished prior to treatment.

Prefabrication or preassembly may be practical on a larger scale if the character of the work permits. The inspector should check all jigs and fixtures used in such processes to make sure that the units are true to exact dimensions within permissible tolerances, and that the units are complete in all respects with attachments, holes for field bolts, and grooves for ring connectors as required. The inspector must also make sure that handling devices for the completed units are adequate to assure their conveyance without distortion or damage. If the material is treated, he must make sure that all cuts and holes are given the surface treatment specified.

ERECTION

The erection plant will usually consist of automotive or locomotive cranes or travelers, with the necessary slings, strongbacks, and lifting devices. The inspector must make sure that the plant is adequate, safe, and in good working order and must record the plant on hand and in use in his daily reports.

The inspector must make sure that the erection methods are safe and capable of performing the work effectively and are of required workmanship and quality. He must make sure that all members are of the correct dimensions and are cut square or formed to exact shape; that they are fitted together truly with full bearing and without shims or other adjusting devices, except as specifically permitted; that bolt holes are round and undersized for drive fit; that all members are aligned correctly; that the work is adequately braced, guyed, or supported at all times to assure against distortion or collapse; and that all bolts, driftpins, ring connectors, and other hardware are of the specified dimensions and materials, are galvanized if required, and are properly installed and tightened or driven to proper depth without damaging the timber. The inspector must reject and require replacement of any timber or hardware damaged during erection. The inspector should make sure that temporary holding or aligning devices are provided and used as necessary to assure tight, accurate work, that these devices do not injure or mar the finished work, and that they are removed upon completion of erection. On work involving the connection of a number of plies of heavy material, it is essential that ample length of tread be provided to allow for future retightening of bolts if the timber shrinks. The inspector must make sure that all other detailed requirements of the specifications are fully met.

CAISSONS

This section relates primarily to the inspection of caissons. Some of the major items to be covered in the inspection of box caissons, open caissons, and pneumatic caissons are given below.

BOX CAISSONS

A box caisson is a hollow structure with exterior walls and a solid floor, but with no top.

It may have internal walls, struts, or diaphragms and may be of timber, steel, or concrete. Box caissons usually are restricted to use for the underwater portion of bridge piers. They are frequently built ashore, launched, towed to the site, and sunk into position in an excavated hole. They are then filled with stone or concrete as required. Occasionally they are landed on timber piles.

The inspector should watch the construction of the caissons to make certain that the construction methods and materials are in accordance with the governing specifications. Care must be taken to make certain that box caissons are watertight before they are launched. After launching, the trim should be inspected and ballast added if necessary, to bring them to an even keel. The bed on which the caissons are to be landed must be carefully excavated and screeded or dragged to a true plane. The character of the material at the bottom of the excavation must be verified against the design data or borings and any deficiencies reported to the proper authority. The caissons must be carefully positioned at the site and their position and trim maintained carefully during sinking. After they have been landed and their position, elevation, and plumbness checked as acceptable, they must be grouted in, if the specifications so require; and after the grout has set, they must be filled with sand, gravel, or lean concrete as specified.

OPEN CAISSONS

Open caissons differ from box caissons in that no floor is provided. They are used extensively for deep foundations and bridge pier substructures and are adapted particularly to very deep structures beyond the limits for pneumatic caissons. They may be of wood, steel, or concrete and are provided with cutting edges to facilitate sinking. If they are to be launched and floated to the site, they must be equipped with some form of buoyancy chambers to assure flotation and stability. In use on land, they may vary from relatively small cylinders, frequently with belled-out bottoms, to extremely large rectangular or cylindrical shapes.

The inspector must understand fully the construction procedure contemplated by the design and the particular features that must be given special attention in the field. If the scheme requires launching, he must understand the provisions in the design for flotation and stability and ascertain that they are incorporated in the first stage of construction before launching. He must make sure that the cutting edge is accurately fabricated, firmly anchored, and properly supported before launching. He must, of course, make sure that the structure, whether of wood, steel, or concrete, is constructed in accordance with the project specifications or the applicable standard specifications.

During sinking, he must keep constant watch of the operations, keep an accurate record of position, plumbness, and rate of sinking, and of all special circumstances or events attending the sinking. He should record the extent of jetting, difficulties encountered in keeping the caissons plumb or centered, boulders or other obstacles encountered, and means adopted to overcome such difficulties.

If a tremie seal is required, he must make sure that the tremie concrete is placed by proper methods to avoid washing or segregation, that the concrete is well cured before the shaft is dewatered, and that the tremie seal is tight before permitting it to be filled. If belled caissons are used in hard clay or hardpan soils, he should inspect the bells to make sure that they are properly formed, are firm or properly supported, and that bell diameters are of the sizes required. If drilled-in caissons are used, he should verify that the drilling has been extended into firm rock for the full distances specified.

PNEUMATIC CAISSONS

Pneumatic caissons are used for installing foundations from 30 to about 100 feet deep when site conditions make it essential that the surrounding soil remain undisturbed, or when logs, boulders, or other subsurface obstructions would make the sinking of open caissons difficult or impracticable. For lesser depths, simpler methods can usually be adopted more economically. For greater depths, pneumatic caissons are impracticable because the air pressure required to balance the hydrostatic head exceeds the maximum permitted by recognized laws.

The inspector must clearly understand the requirements regarding the construction of pneumatic caissons. In most cases, the caissons will be fully detailed on the drawings and the requirements fully prescribed in the specifications. Because of the highly specialized nature of the work, the inspector must not dictate methods of special measures in emergencies, but must make sure that the necessary safety measures for the protection of both the men and the work are taken.

The inspector must make sure that pneumatic caissons are properly seated at the start and adequately supported against premature sinking, that they are accurately positioned and vertically set, and that the air locks and air supply pipes are in perfect working order before air is applied. As sinking progresses, the inspector should keep detailed logs of the rate of progress and a record of all troublesome incidents. The inspector must make sure that the caisson is maintained substantially vertical and report immediately to his superior any material difficulty experienced in correcting tilt or any other unsatisfactory occurrences.

When the caisson is landed, the inspector must make sure that the bed is properly leveled and cleaned; that belled bottoms, when required, are provided as specified; that concreting of the air chamber is carefully done; and that sealing and grouting are completed effectively, if required.

COFFERDAMS

Cofferdams are temporary structures enclosing an excavation, either on land or in the water, so that the work may be performed in the dry. If in water, they must be strong enough to resist hydrostatic head from maximum high water to the mud line and the lateral pressure of saturated soil from the mud line to the bottom of the excavation. If on land, they must resist the pressure of dry earth above the ground water line and of saturated earth below it. They must be substantially water-tight and must penetrate far enough below the bottom of the excavation to afford an adequate cutoff to minimize seepage, blowouts, and boils through the bottom of the excavation.

The inspector is responsible for inspection of the construction and maintenance of the cofferdam from the stand of safety of the work as a whole. He should familiarize himself with the approved plans for the cofferdam and with the basic principles on which it was designed, and is expected to act so that he can determine intelligently whether the work is being performed correctly and in proper sequence for safety.

In some cases, various types of fixed or floating templates, or other alignment devices such as guide piles, are provided to establish and maintain the lines of the cofferdam walls. The inspector should make sure that they are laid out so that the permanent structure can be built within the cofferdam without interference, with due allowance for possible deflection or displacement of the cofferdam.

The inspector should watch the construction of the cofferdam and satisfy himself that sheet piles are being driven to the depths indicated, that piles are properly interlocked, that bracing is installed and adequately wedged before excavation or dewatering has proceeded too far, that any berms or embankment needed for the stability of the cofferdam are constructed in time, and that any clay blankets shown to decrease percolation are installed before pumping is started. He should make certain that adequate pumping plants or well-pointing systems have been provided and are in working order. The inspector should point out any seeming deficiencies in workmanship or sequence of work, and should keep his superior informed of any serious deficiencies that are left uncorrected.

The cofferdam should be maintained in an acceptably dry condition during the construction of the work being built within it. The inspector should maintain general surveillance of the condition of the cofferdam and point out any evidences of weakness. He must require that the cofferdam be kept dewatered to the level necessitated by the work in progress. He should keep a complete record of all emergency conditions arising and of the measures taken to correct them. The principal troubles arise from leaks, blowouts under the walls, scour outside the walls, overtopping in floods or at extreme high tides, settlement of the cofferdam, crushing of the internal bracing, or failure of the wales. The inspector must not initiate any action himself to effect emergency repairs but must deal with emergency situations through the principal foreman on the spot. Most emergency situations develop slowly enough to permit correction if caught in time. Others occur so quickly that nothing can be done before the cofferdam is flooded. If such a situation develops, the inspector should inform his superior immediately; endeavor to find the causes, for the record; ascertain the repair procedures proposed; and obtain the approval of them by his superior.

Special care must be taken to guard against fire, particularly in cofferdams braced internally with timbers. The inspector must require immediate correction of any hazardous situations noted.

When the permanent work that has to be built within the cofferdam has been completed and found acceptable, the entire temporary structure must be removed, except that the specifications may provide that sheeting may be cut off below ground level or at some elevation below water level and left in place. The inspector must make sure that the structure is entirely removed, except as otherwise provided or authorized by his superior.

WHARVES AND PIERS

The construction of wharves and piers involves the use of steel, concrete, or timber. Inspectors assigned to such projects must be thoroughly conversant with the inspection of the applicable types of construction, and with requirements for inspection of the materials entering into several types of work. This discussion deals with the inspection of wharves and piers that involve three types of construction; they are open timber pile construction, filled timber pile construction, and concrete piers on piles. An inspection of wharves and piles may also include drainage, utilities, and so on; with space being limited, however, these areas of work are not covered here.

OPEN TIMBER PILE CONSTRUCTION

Open timber pile construction is the cheapest and generally the least durable type of construction for wharves and piers. Durability is increased by the preservation of the timber piles and framing, at greater cost. Usually this type of structure consists of timber piles, caps, stringers, and decking, with accessories such as fender piles, wales and chocks, guardrails, tracks, mooring devices, and utilities.

The inspector must make sure that the approved sequence of work is followed. In some cases, dredging of the site must precede all construction in order to preclude unbalanced lateral pressure against the piles, which might occur if the dredging were deferred until after completion of the structure. In some locations where soft mud is present to considerable depths, the drawings and specifications may require removal or displacement of this mud to a given depth, and replacement with a sand island to provide better bearing and resistance to lateral forces. The inspector must make sure that the methods used assure full removal or displacement of the mud to the required depth, that the sand is of specified quality and gradation, that it is placed in a manner that assures its deposit within the specified limits without undue admixture with mud, and that it is allowed time for consolidation before the structure is built. Driving of piles, however, aids in this consolidation.

The inspector must make sure that the piles are driven to the specified depth or penetration, that they are cut off true and level at the specified elevation, and that they are in accordance with the specifications in all respects. He must make sure that all timber is of the correct size, species, and treatment and that hardware is of full size and length, is galvanized when specified, and is installed properly. He must assure the use of wooden shims only as permitted by the specifications. When creosoted piles or timber is required, he must make sure that all special requirements therefore are faithfully met. The inspector must assure the complete and correct installation of all pipes, conduits, and other services, without cutting of strength timbers, and make sure that all fire stops shown are provided as specified.

FILLED TIMBER PILE CONSTRUCTION

In some localities not subject to marine borer attacks, a filled timber pile type of construction is used. Untreated timber piles are cut off just above low water and decked over with timber caps and planking. Concrete curtain walls are constructed along the face of the wharf or pier and anchored to the deck. Earthfill or sandfill is placed on the deck behind the curtain walls to subgrade elevation, and is compacted. Concrete or bituminous pavement is constructed on the fill. Utility tunnels, services, and tracks may be combined with the curtain walls, may be supported on concrete walls or piers built on the deck, or may be constructed in the fill.

This type of structure requires extensive low-tide work, frequently necessitating a special schedule of working hours. In addition to the usual inspection requirements for timber piers, the inspector should give special attention to the requirements for keying and anchoring the curtain walls. He must also make sure that requirements for spacing between deck planks are carefully followed. Too wide an opening permits escape of fill; too narrow an opening may result in buckling of the planking as the wood swells. The inspector must make sure that all structures supported on the deck are installed before the fill is placed, and that the fill is thoroughly compacted under any ducts, pipes, or other installations supported on the fill.

CONCRETE PIERS ON PILES

Many piers are built with reinforced concrete beam and girder decks supported on reinforced concrete or steel H-piles. Wharves of this type may also be built with sheet-pile bulkheads on the shore face of the wharf.

The inspector must give special attention to the driving of piles to make sure that they are accurately aligned and are driven to adequate penetration and bearing value. If they are of reinforced concrete, he must see that they are free from cracks that might cause rapid deterioration, particularly in salt water. If they are of steel, he must make sure that any special protective coating called for in the range between high and low water is properly applied and is at the specified elevation after driving is completed. He must be quick to have the limits of coating modified to suit if the penetration being obtained changes. He must make sure that the reinforcement in the piles is anchored in the caps or girders and that the reinforcement for the latter is installed exactly as shown, to assure that the degree of fixity at the top of the piles contemplated by the design is actually obtained. He must make sure that any conduit or pipes in the slab, any inserts for supporting pipe or duct hangers or for anchoring fenders, and any anchor bolts or other accessories to be set in the concrete are installed and checked in detail before concrete is placed. He must make sure that the specified minimum clear cover is obtained between the reinforcement and the underside of the slab. Serious deterioration of many concrete piers has resulted from failure to comply with requirements for cover over the steel.

BRIDGES

Highway and railroad bridges are required at numerous naval activities, either within the activity or on access roads and connections adjacent to it. Points to be covered in inspecting bridge construction are given below. In addition to these check points, various inspection requirements given in other sections of this chapter may also apply, since bridge construction often may involve different types of work, such as pile driving, cofferdams, concrete, and so on.

CONSTRUCTION

In inspecting bridges, the inspector must avoid dictating construction methods or interfering with the choice of methods. He must, however, make sure that the methods assure satisfactory results and take steps to obtain their modification if they do not.

Inspectors must make sure that the plant is adequate, safe, and properly maintained. Special care must be taken to ascertain that erection travelers are adequately counterweighted to assure stability when lifting loads at maximum capacity and reach. If the erection scheme requires placing prefabricated spans by floating them to the site and lowering them into position by flooding the barge or barges, the inspector must satisfy himself that the floating equipment is stable during all stages of the operation and that flooding can be controlled accurately.

Many bridge projects require careful scheduling of the sequence of operations where interference with highway, railroad, or waterborne traffic is involved. In such cases the inspector must review in advance the schedule proposed, make sure that it meets the requirements of the project and the approval of his superior, and determine that it is followed when approved. If circumstances arise that necessitate modification of the schedule, his superior should be informed.

SPECIAL INSTRUCTION REQUIREMENTS

A basic requirement for inspection of the ACCURACY OF CONSTRUCTION is that the finished structure must be visually true. For example, curbs, and railings must be free of waviness, have true straight edges, and be uniform throughout. Defects are magnified because they are usually seen in foreshortened perspective. They can be avoided only by conscientious, competent workmanship, which is difficult to define exactly in specifications. Much depends on the capacity and intelligence of the inspector. He should have a clear understanding with the foreman or others concerned of the necessity for complying strictly with the basic intent of the specifications regarding quality of workmanship, and see that this intended quality is obtained. There are many other phases of the work on which special attention must be given to accuracy, some of which are more important to the structural integrity of the work.

On TIMBERWORK, for example, the inspector must make sure that members are cut square and to exact length so that they fit and bear fully without shimming. He must ascertain that bents are set truly vertical, that batter piles are on a uniform batter, that the tops of stringers are set truly in a level plane, that decking is of uniform thickness, and that guardrails are straight and uniform.

On CONCRETEWORK, the inspector must verify that forms are set exactly to the prescribed lines and dimensions and that they are free from waviness or other irregularities. He must make sure that the finished work conforms to these lines and dimensions. He must determine that reinforcement is spaced accurately and that the required cover over the steel is obtained. On highway bridges he must make sure that the specified crown or superelevation is maintained, and must require the use and adjustment of templates or finishing machines as necessary to obtain the results required.

Special attention must be paid to the accuracy of erection of STEELWORK to make sure that excessive drifting of holes is not needed in riveted work, that internal stresses are not introduced in welded work, that the specified camber is obtained, that girders and trusses are erected in a vertical plane without lateral distortion or side thrust or tension from transverse members of inaccurate length, that secondary members fit without tension or slack, and that all joints make up without the need for springing members to make gage lines match.

Bridge piers located in the water may require caissons for construction. In addition, cutoffs of piles under water, placing of tremie seals, and cleaning of the bottom before construction of the piers is started must be carefully checked by the inspector. If circumstances arise that justify inspection by divers on any part of the work, the inspector should notify his superior so that arrangements can be made. The inspector should cooperate closely with the diver assigned, make sure that there is complete mutual understanding as to the specific conditions to be investigated and as to the conditions revealed by the diver's inspection, and should supplement the diver's written report by his own independent report of the conditions reported.

DETAILS

Most major bridge piers are concrete structures supported on piles. Stone masonry facing may be used on important bridges for architectural effect or near the waterline on utilitarian bridges for protection from ice or other destructive actions. Steel or wrought-iron plates are also used for the latter purpose.

In underwater work, the inspector must make sure that any soft mud on the bottom is removed and replaced with acceptable material, if so specified, and that piles are driven accurately in the correct positions and to the penetration and bearing value prescribed and are cut off at the specified elevations. He must make sure that caissons or cofferdams are of the correct size, are accurately centered both longitudinally and transversely, and are plumb and watertight. If tremie seals are required, the inspector must make sure that the concrete meets all requirements; that tremie plant and methods assure placement of concrete within the mass of concrete, without permitting it to be dropped through water; and that the thickness of the tremie seal is the full thickness specified.

In the case of work performed in the dry, the inspector must make sure, when the caisson is unwatered, that the seal is tight and that the surface is cleaned and leveled if necessary. He must give particular attention to the quality of the concrete and the workmanship in placing it so as to assure dense, high-strength concrete free from honeycomb and having maximum durability under extreme conditions of exposure. He must make sure that any anchors required for securing masonry or armor are provided and firmly embedded as specified, and that the masonry or armor is correctly installed so that it can withstand the great forces that may be imposed on it by ice or debris. Special care must be taken to ascertain that the upper surfaces of piers are brought exactly to the required elevations and are finished to true plane.

The inspector must make sure that BENTS are accurately aligned and truly perpendicular to the longitudinal axis of the bridge. In many cases, templates will be necessary to assure accurate positioning of piles. The inspector must make certain that bridge seats are finshed at the correct elevation and to the required plane or contour.

In addition to the general requirements for inspection of the concrete or other work involved, the inspector should check ABUTMENTS for settlement after fill has been placed against them. Settlement of approach embankments frequently occurs on soft ground because of the weight of the fill and induces settlement of the abutment. If settlement is detected, the inspector should inform his superior promptly.

The inspector must give special attention to the strength of FORMS and FALSEWORK and the adequacy of their SUPPORTS to make sure that displacement and settlement will not occur. If any appreciable movement takes place when concrete is placed, steps should be taken to remove the concrete before it has set.

Special care must be taken to determine that BEARING PLATES are of the materials and dimensions specified, and that they are set accurately and solidly. Plates for sliding expansion-joint bearings should be set so that the tool cuts are parallel to the direction of sliding. Rocker supports must be leveled and aligned so that each rocker participates fully in supporting the load throughout the full range of movement. The inspector must check their installation with great care and make certain that they are set at the proper position in their range to suit the temperature at the time of installation.

On highway bridges special care must be taken to obtain uniformly textured SURFACES with true lines and sharp edges for all exposed surfaces. The specifications may prescribe higher class finishes for surfaces visible from the bridge roadway. The inspector must make sure that the foreman or supervisor knows in advance which surfaces must have the higher class finish and see that it is furnished. The inspector must make sure that the roadway is crowned or pitched as specified.

The appearance of bridges is affected to a great degree by the quality of workmanship on the RAILINGS. In many cases, precast or prefabricated rails are specified to assure factory-grade precision, and designs provide for field adjustment to facilitate visually accurate alignment. In such cases, the inspector must check the rails on delivery for quality and workmanship and must also check the installation before the adjusting devices are sealed in to make sure that the rails have been correctly aligned. If cast-in-place railings are prescribed, the inspector must give special attention to the type, quality, and installation of the forms to make sure that highly accurate railings are assured. Factory-made forms, usually of steel, are frequently used to obtain high-grade work.

EXPANSION JOINTS are required for practically all bridges. Frequently they are provided over every pier or over every other pier. On highway bridges special expansion combs are sometimes installed in the roadway slab to support the wheels across the joint and to reduce impact. Alternatively, the slab edges at the joint may be protected by steel angles, with or without sliding plates. The inspector must make sure that the devices provided conform to the requirements, are set truly perpendicular to the axis of the bridge, conform accurately to the contour of the roadway surface, and are rigidly anchored as required. Special care must be taken to make certain that the two matching members on either side of a joint fit each other in elevation and, if of interlocking-comb type, that the fingers fit into each other with balanced clearance in each side.

APPURTENANCES

Special care is necessary in inspecting the construction of bridge approaches to make sure that all the steps specified to minimize settlement have been taken. Otherwise, a depression may develop adjacent to the abutment that will give the highway or track unsatisfactory or even dangerous riding qualities. In some cases, a reinforced concrete transition slab may be specified to prevent this condition from developing. The inspector must determine that the transition slabs, if specified, are properly supported on the abutment, properly reinforced, and of full thickness.

Fenders will usually be required on either side of the channel span. They also may be required around other piers for protection from ice, debris, or collision. The inspector must make sure that they are strongly built. He should pay particular attention to the adequacy of all fastenings. Fenders are subjected to heavy impact and are designed to resist these blows in part by yielding and in part by spreading the force along the fender.

If lighting is specified, the inspector must make sure that conduits, ducts, handholes, and fixture outlets are installed progressively in the bridge structure. He must ascertain that lighting standards are rigidly fastened and are plumb and in alignment. He must make sure that all wiring is of the specified type, is carefully installed, and is tested for grounds and insulation resistance. He must make sure that the system is given an operation test and must check all features for compliance with requirements.

CONCRETE PAVEMENT

Portland-cement concrete pavement may be plain or reinforced, may be of uniform thickness or of thickened-edge type, and may be constructed with either Type I or Type III cement, with or without air entrainment.

The inspector should note that concrete for pavements is usually tested for flexure rather than compressive strength. He must ensure that flexure test specimens are prepared at the site in the number specified and delivered promptly, without damage, to the laboratory. The inspector must also make sure that expansion-joint materials, load-transfer devices, reinforcement, and other accessories conform strictly to the requirements, if not previously factory inspected.

On major paving jobs, the concrete is ordinarily mixed at the site in a paving mixer of the boom and bucket type and of not less than 1 cubic yard batch capacity, equipped with complete weighing, timing, and controlling devices. In some cases, aggregates and cement are preweighed and delivered in trucks equipped with batch boxes. The inspector must check all equipment; verify the accuracy and calibration of all scales, timers, and controls; and make sure that the equipment is operated in accordance with requirements, delivers concrete of uniform consistency in unsegregated condition, and distributes it uniformly on the subgrade.

After concrete is placed, it is struck off and compacted and finished mechanically with a power-driven machine, traveling on the side forms, until all voids are removed and the concrete thoroughly compacted and shaped to substantially the final contour. The inspector must ascertain that the finishing machine is in first-class working order, is operated by a skilled operator, and is adjusted so as to assure the required crown on the final finished surface, allowing for sag when spanning between the forms.

The inspector must make sure that all trucks handling aggregate are tight, that batch boxes when used are large enough to hold a full batch without spilling, and that cement containers are weathertight. If a central mixing plant is approved or the use of transit-mixed concrete is permitted, the inspector must determine that the subgrade is not adversely affected by the delivery of concrete, and must require correction of any rutting or other damage. He must make sure that the concrete as delivered is not segregated, and must reject concrete that has been mixed more than the maximum specified time.

Concrete pavement is placed between side forms, generally of steel channel shaped, of the same depth as the thickness of the pavement and with a broad base. Wood forms are usually permitted only on curves of small radius. The inspector must make sure that forms: (a) are of approved type, of proper depth and of specified weight, stiffness, and width of base; (b) are straight and true; (c) are accurately set to true line and grade; (d) are supported so that they are capable of sustaining without settlement the weight of the finishing machine or other equipment to be operated on them; and (e) are adequately joined, braced, and staked immovably in position. He must verify that forms are thoroughly cleaned and oiled before reuse.

Immediately before concrete is placed, the inspector must check the subgrade and make sure that it is true to line, grade, and contour and is uniformly compacted; that all defects have been corrected; and that it has been thoroughly moistened by watering the night before.

Placing of concrete on frozen subgrade must not be permitted. Mixing and placing of concrete is usually permitted when the air temperature is 35°F and rising, but prohibited when the air temperature is 40°F and falling. The limitations imposed by the specifications must be enforced. The inspector must make sure that concrete mixes conform to the approved design mix, are within the specified range of slump, have been mixed for the specified minimum time at the prescribed rate, are uniform in quality, and are uniformly distributed. He must make certain that concrete is well spaded along forms and at joints. He should require placing of concrete to be stopped in time to allow finishing to be completed during daylight hours.

The inspector must give special attention to the installation of all joints. Transverse expansion, construction, and contraction joints will usually be required on all jobs. Longitudinal joints for similar purposes may also be required, but may differ in details. The inspector must make sure that the joints conform in type and location to those shown or specified and that they are installed accurately and solidly. Dowel bars must be oiled or painted as specified and must be set exactly normal to the joint. If expansion sleeves are required, the inspector must make certain that they fit accurately, allow the specified slip, and are tight enough to preclude entry of mortar. The inspector must give special attention to the assembly and support of load-transfer devices. If joints are required to be raked and filled with a poured filler, the inspector must make sure that the filler is of the specified type and proper consistency to fill the joint without flowing toward the gutter.

The attention paid to finishing operations affects greatly the appearance and acceptability of a concrete pavement. The inspector must make sure all surplus water, laitance, and inert material are worked off by scraping or squeegeeing with a straightedge of T section operated from parallel bridges resting on the side forms, or by a mechanical longitudinal float, working from the crown toward the gutter. Any pockets or marks caused by this scraping must be repaired by reworking the surface with hand floats. If required, the inspector must make sure that the surface is belted with a clean canvas or composition belt and checked with a straightedge, that variations exceeding the specified tolerances are corrected, and that the surface is given a final belting to produce a uniform texture. The inspector must make certain that all edges are rounded with an edging tool and that a strip of uniform width, generally 2 or 3 inches, adjacent to all joints is finished with a wood float, to assure that the surface on both sides of the joint is at the same grade.

The inspector must make sure that the concrete pavement is covered and cured for the full period specified, usually at least 72 hours, by one of the optional methods permitted by the specifications, such as ponding, and so on. If membrane waterproofing is used, the inspector must make sure that the full number of coats specified is applied, and that all bare or imperfectly coated spots are recoated. If freezing weather is anticipated, it may be necessary to require covering the fresh concrete with hay, straw, or grass to protect the surface from freezing.

The specifications usually prescribe a maximum acceptable variation from true grade of 1/8 inch measured as an ordinate from a 10-foot straightedge placed parallel to the centerline. If the pavement is crowned transversely, a crowned template may be required for checking deviations from the required contour. Specifications may require tests for pavement thickness, usually by cores taken at specified intervals. The inspector must keep an accurate record identifying the exact location of each core and giving its thickness. He must make sure that the holes left by corings are satisfactorily repaired and finished.

CHAPTER 11

MAINTENANCE INSPECTION

However well a structure is constructed initially, proper maintenance and repairs are necessary from time to time to keep it in first-class condition. An effective maintenance inspection will disclose whether specific types of maintenance or repairs are needed on buildings or other structures. The maintenance program should be designed to (1) promptly detect deficiencies and damages, and (2) expeditiously perform economical and workmanlike repairs. These requirements are essential if the maintenance standards are to be achieved.

Detection is provided by inspection of facilities at regular scheduled frequencies by qualified inspectors. The inspection program should also include emergency inspections prior to and following unusual and severe storms where high velocity winds, abnormal tides, and heavy wave action have been experienced; when heavy snowstorms and extremely low temperatures are anticipated or experienced; and after the occurrence of any operational hazards. In some instances, an inspection will turn up minor defects which can be corrected promptly and, as a result, prevent the occurrence of major defects requiring extensive repairs. As a Builder, you may be called upon to conduct maintenance inspections at Navy activities. This is a responsible job and one that should be assigned to well qualified personnel.

The types of structures that you inspect will depend upon the types available at your activity. So, consider those discussed here as typical of the many types that you will find at some activities. Let us emphasize, too, that this instruction is not intended to list every item that should be checked during an inspection of a specific type of structure. Additional and more detailed information applicable to the maintenance inspection of structures, roofing, painting, and waterfront facilities can be found in the appropriate MOs which are published by NAVFAC and listed in the *Index of Naval Facilities Engineering Command Publications,* NAVFAC P-349.

At some activities, forms may be available on which a check list is provided showing major items to be covered in the inspection of the structure concerned. These forms may be prepared locally, and therefore may differ from one activity to another. At times, of course, forms may not be available and the inspector will have to depend upon past experience in building and construction, as well as sound judgment, in determining what to look for in the inspection.

After completing an inspection, you may have to make a written report on your findings. You may also make recommendations on the type and extent of repairs needed to correct certain defects. You must remember that each inspection is important and should be done carefully, thoroughly, and with safety in mind.

INSPECTING BUILDINGS

There are many check points to be covered in a maintenance inspection of buildings, especially when the inspection extends from the basement up to and including the roof. We will not attempt here to cover all items that might involve a complete and thorough inspection of an entire building. We will, however, cover some of the primary items of concern to the inspector at Navy activities.

BUILT-UP FOUNDATIONS

The foundation of a building transfers the dead and live loads of the superstructure to soil that has enough bearing capacity to support the structure in a permanent, stable position. Footings are used under foundation components–such as columns and piers–to spread concentrated loads over enough soil area to bring unit pressures within allowable limits. Foundation design is determined not only by the weight of the superstructure but also by occupancy or by use of the building or structure and by the load-bearing capacity of the soil at the size. The latter conditions may change and introduce maintenance and repair problems even in initially well-designed foundations.

Foundations should be inspected at least annually and more often where climate, soil conditions, or changes in building occupancy or structural use present special problems. Evidence of incipient foundation failure may be found during routine inspection of other structural components.

Foundation Displacement

A foundation should be checked regularly for proper elevation and alignment. Complete failure in a foundation is rare; however, some settling or horizontal displacement may occur as shown in figure 11-1. Common causes of foundation movement include: inadequate footings; overloading the structure; excessive ground water, which reduces the bearing capacity of soil; inadequate soil cover, which fails to protect against frost heaving; and adjacent excavations that allow unprotected bearing soil to shift from under foundations to the excavated area.

Severe, localized foundation displacement may show up in cracked walls, damaged framing connections, sloping floors, sticking doors, and even leakage through a displaced roof.

Corrective actions taken to alleviate foundation displacement include the following:

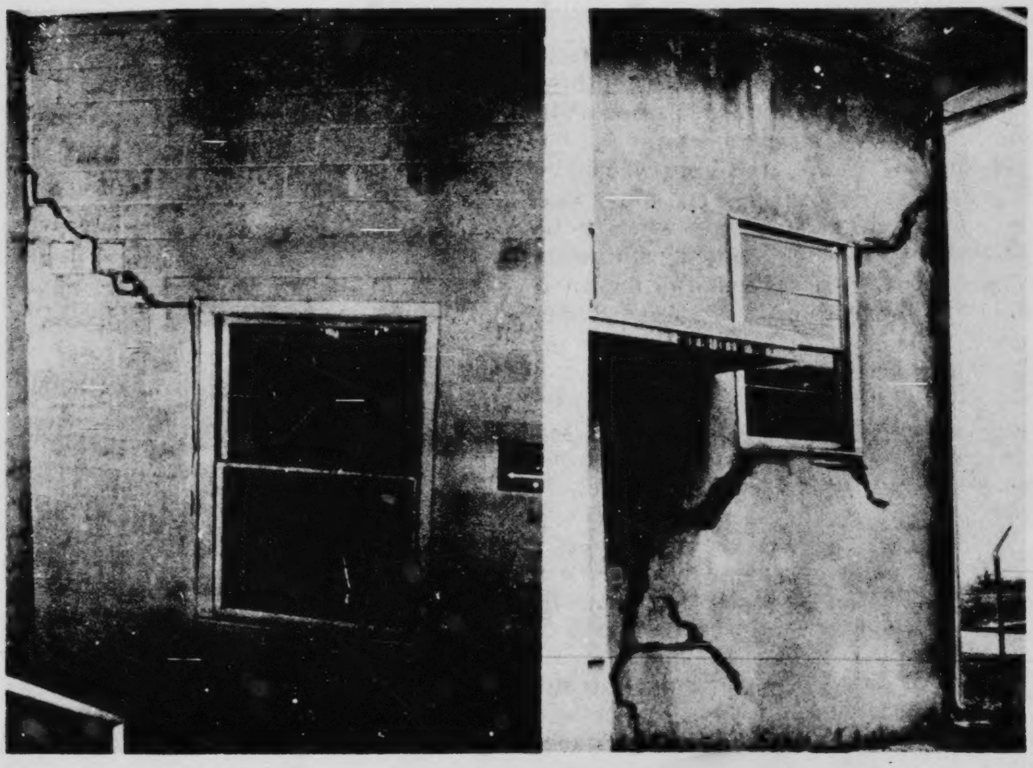


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Figure 11-1. –Signs of foundation displacement.

- Replace immediately any missing or dislodged part of the foundation; repair cracks or open joints in concrete or masonry foundation walls; replace defective wood members.

- Provide proper drainage away from buildings and structure.

- Replace unstable fill around the foundation with clean, properly compacted fill.

- Remove growing roots of trees or shrubs that may dislodge footings or foundations.

- Increase bearing area of inadequate footings.

- Maintain enough soil cover to keep footings below the freezing zone.

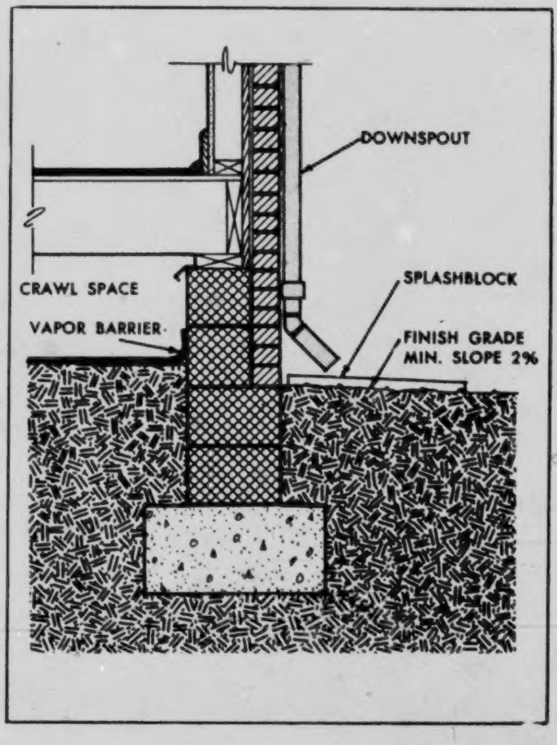
- Prohibit loads exceeding the design loading of buildings and structures; isolate foundations from heavy machine operations by providing independent footings and foundations for heavy machines. Air conditioning equipment, cooling towers, and compressors should be provided with cork or rubber isolation mounts to prevent transmission of vibrations to the structural frame of the building.

When excavations are made near the footings of buildings, care must be taken in removing bearing soil under existing structures. To relieve pressure of the footings on the soil, shoring, underpinning, or needling may be required for temporary stabilization. Sheet piling may be driven and supported laterally to contain the bearing stress in the soil under the footings.

Where water erosion removes soil from around and under footings, some means of erosion prevention, such as ditching or use of splash blocks, must be used.

Footings that fail because of insufficient bearing area must have their bearing area increased. The amount of movement in the wall dictates the repairs necessary. Minor settlement, especially when uniform, may require no repair. If serious settlement occurs, the wall may have to be jacked back to its original elevation, a new footing provided, and repairs made to the wall.

Improved drainage is the basic solution to the most common ground water problems (see fig. 11-2). Moisture in structures caused by a high water table can be drained away from a foundation by the installation of open-joint tile drains surrounded by loose gravel fill. The drains should be laid so as to drain the water away from footings and wall into a sump with float-controlled electric pump. To be effective, a tile drain should generally be pitched from a high point around the perimeter of the building to a low point below the floor slab where the sump and pump are located. Where roof drainage causes a foundation water problem, gutters and downspouts should be installed, preferably connected to a storm sewer. Gutters that are improperly hung or allowed to become clogged will overflow and lose their effectiveness. Leaks in gutters should be repaired promptly. Splash blocks or tile drain should be installed in the absence of storm sewer connections to prevent pooling of water below downspouts. The drainage of surface water toward a building can be reversed by sloping the



117.428

Figure 11-2. —Proper drainage for storm water.

ground surface away from the foundation wall. Where that is not practical, ditching or installing tile drains will serve the same purpose. The general grade of crawl spaces should not be lower than the surrounding area, which should be graded to drain away from the building.

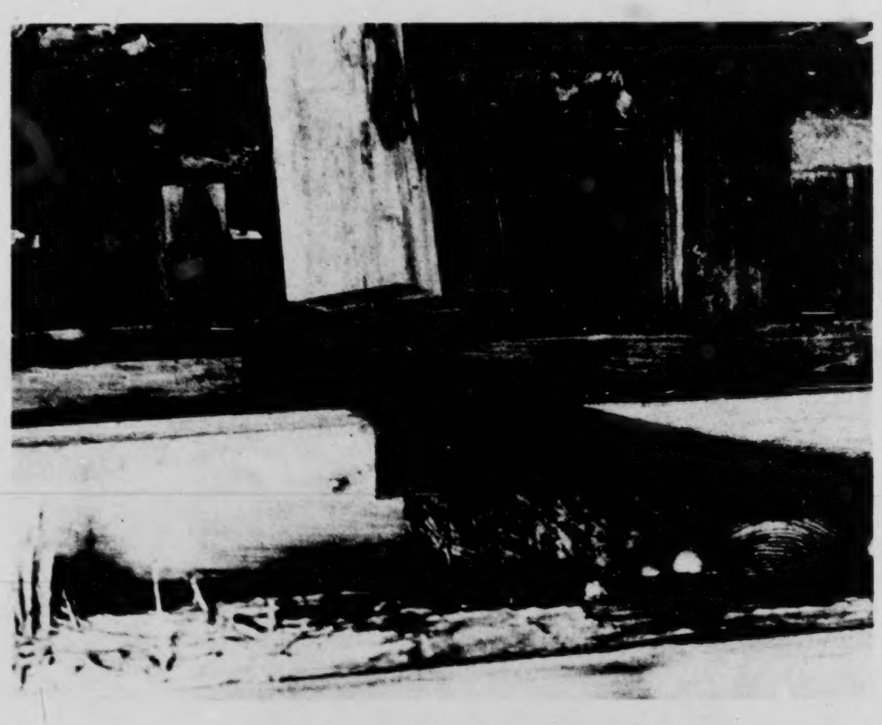
Material Deterioration

Foundations are subject to deterioration, whether from material or construction deficiencies or from environmental conditions. The deterioration of foundation materials must be observed directly unless the effects are severe enough to cause foundation settling. Excessive moisture from surface or subsurface sources is a major cause of timber deterioration, providing the necessary condition for wood decay and encouraging insert infestation. Improperly seasoned wood is subject to cracking, splitting, and deflection. Concrete and masonry are subject to cracking, spalling, and settling, particularly under adverse ground and climatic conditions. Steel and other ferrous metals are subject to corrosion in the presence of moisture and sometimes by contact with acid-bearing soils. Signs of corrosion are darkening of the metal, rusting, and pitting.

Corrective actions taken to alleviate the deterioration of the foundation materials given above are covered in detail later in this chapter in the section dealing with the maintenance and repair of waterfront structures.

CRAWL SPACES

Considerable deterioration extending from the foundation to the building superstructure can be caused by neglect of crawl spaces, especially in climates where it is necessary to enclose the space to maintain comfortable floor temperatures (see fig. 11-3). Unventilated crawl spaces contribute materially to rapid absorption of moisture into structural wood and other



117.299

Figure 11-3. —Damage caused by neglect of crawl space.

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materials, and the spaces soon become a natural habitat for fungus growth and termites. Sills, joints, and subflooring may be affected by wood decay. Condensation may occur in the studding spaces above the floor level and cause paint failures.

Crawl spaces should be carefully checked periodically. In checking these spaces, ensure that they are clean, clear, and accessible. An accumulation of rubbish in the space may provide a natural harbor for insects and rodents, as well as impede access and possibly interfere with drainage. Scrap wood is a clear invitation to termites.

Look for disorganized storing of any material in crawl spaces. Also, check for accumulations of water that may breed mosquitoes, cause fungus growth, and weaken soil bearing under footings.

Ensure that all ventilation openings are covered with suitable hardware cloth or copper screening to prevent entry of birds and rodents. In addition, see that access doors to crawl spaces are provided with a suitable padlock and kept closed.

Wood Decay

Wood decay is caused by wood-rotting fungi that grow in damp wood. Fungi attack wood members in contact with damp masonry foundations, moist ground or standing water, and water pipes that accumulate condensation or on which moisture condenses. Poor ventilation around the wood hastens the process of decay.

Wood decay is indicated by:

- A damp, musty odor.
- Opening or crumbling of the wood.
- The pressure of fine, dusty, reddish-brown powder under the building.
- A hollow sound when the timber is tapped.
- Easy penetration of timber by a sharp-pointed tool.

Corrective actions taken to alleviate wood decay include the following:

- Remove fungus-infested lumber. Spray infested areas with wood preservative conforming to Federal Specification TT-W-571.
- Eliminate the source of moisture. Add fill around masonry and grade swales to lead water away from the foundation. Where land contours do not promote runoff, install drain tiles around the foundation and lead them to a storm drain, or provide a dry well at a lower elevation than the water table at the foundation.
- Provide ventilation to affected areas.
- Replace infested lumber with lumber treated with wood preservative conforming to Federal Specification TT-W-572.

Termite Control

An inspection should include a check, where applicable, for termites. Wood and wood-and-masonry members are susceptible to termite attack. Subterranean termites become established in wood that is in contact with moist soil. Their presence may be indicated by earthlike shelter tubes leading from the ground to the infested wood. Dry-wood termites live all their lives in dry, sound, and seasoned wood. A reliable sign of dry-wood termite attack is the finding of pellets in the immediate area. Among basic methods of preventing termite infestation are soil treatment, use of wood preservatives (such as pentachlotophenol), removal of surplus wood and other debris from the site, preventing contact of lumber with the ground, and covering openings into attic spaces with suitable hardware cloth or copper screening.

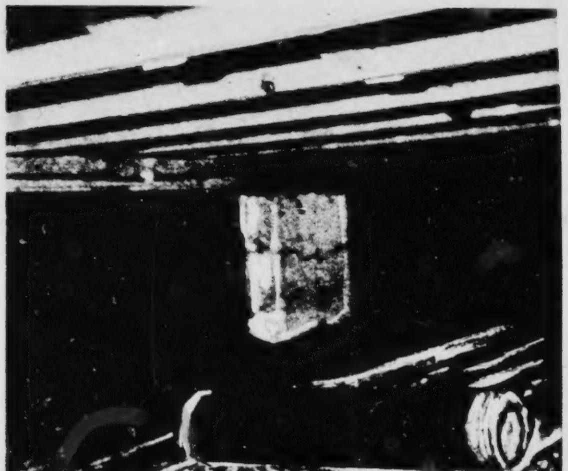
Moisture Control

In crawl spaces or "dead" areas under basementless structures, moisture control problems other than building drainage develop from condensation of moisture rising from damp soil. The ideal method of preventing ground moisture from entering the building is to provide an impermeable vapor barrier on the warm side of insulation in floors and walls. In existing buildings this is not practical unless it is done in the course of major renovation.

The most practical solution is to provide a soil cover of water-resistant material as shown in figure 11-4. Fifty-five pound roll roofing has been the most widely used and successful soil cover; however, recent tests indicate that 0.006-inch polyethylene plastic sheeting is effective and lighter to handle than roofing paper. The effective life of these plastic covers has not been established when used exposed to the air or under slabs. Soil covers may be rolled out on the soil from foundation wall to wall. It is not necessary to form a complete seal over the soil, but more than 90 percent of the soil should be covered, and cracks should be limited to 1 inch. Removal of trash and debris and leveling of sharp dips and mounds in the soil will increase the life of the cover.

BASIC SUPPORTING MEMBERS

For inspection purposes, the basic supporting members of wood frame structures are divided into three groups which are (1) sills and beams, (2) posts and columns, and (3) girders and joists.



117.429

Figure 11-4. –Application of 55-lb felt soil cover.

Sills and Beams

Inspection and timely repair of sills and beams set on foundation walls, piers, or columns are important to the general maintenance of a structure. As in the case of uneven settlement of the foundation, severe damage can be done to the basic building by a reduction of the ability of the sill or beam to maintain upper components in their fixed position. Sill and beam defects can lead to many lesser but troublesome and expensive repairs of wall and ceiling cracks and misaligned doors and windows. Wood sills and beams should be inspected periodically for rot and insect and rodent damage.

Sills and beams should be kept to correct grade by the use of slate or steel shims and mortar pointing. Reinforcing plates, extra tie-downs, or other means should be used to correct misalignment. Timbers exposed to ground moisture or severe weathering must be treated often enough to prevent deterioration, and sufficient ventilation assured to avoid rotting.

Posts and Columns

Periodic, thorough inspection should be made of all posts and columns in contact with the ground, to prevent deterioration. They should be treated with a preservative to resist decay and damage by termites. Posts and columns should be maintained plumb and in alignment. Inspection of posts should include a test for soundness, made by jabbing the post on all sides with an icepick or other sharp instrument; the amount of penetration indicates the soundness of the wood. In most soft woods, such as pine and fir, the pick should not penetrate more than 1/2 inch; in hardwoods, such as gum and oak, penetration should not exceed 3/8 inch. Columns are more difficult to inspect in finished buildings, but when there are indications that columns are out of plumb, the covering finish material should be removed and a thorough inspection made. Out-of-plumb or misaligned columns may be indicated by cracks in plaster or other finish, but the same defects may be caused by failure of other structural components. Repairs and/or replacement work should not be made until the true cause of defects has been established.

If the foundation is not level because of uneven settling, the defect should be corrected before any attempt is made to plumb or align posts or columns. The floor above should then be shored with jacks or other devices, and the supporting members plumbed and realigned.

Posts or columns that show signs of failure caused by overloading should be surveyed by an engineer competent to recommend repairs or replacement in terms of overall structural soundness.

Girders and Joists

As with the other basic supporting members, periodic inspection and timely repair of girders and joists are important to the general maintenance of a structure. Wood joists and girders are usually of a size that is not easily dried; consequently it is normal to expect shrinkage and seasoning splits and checks.

Checks and splits should be carefully recorded as to size, location, and depth. If records indicate increases in length or depth, then stitch bolts may be required. Stitch bolts are required in all structural members that have deep checks or splits 3/8 inch or greater in width and/or having slope of grain greater than 1 inch in 14 inches.

In the event of a structural failure, an engineering study should be made to determine whether the failure can be properly patched or if the entire girder or joist should be replaced. Many methods can be used to reinforce girders and joists, and the selection of the proper methods should be determined by the loads to be carried, the cost, and clearance and accessibility. When either a permanent or temporary post is placed under a failure of a girder or joist, consideration of size of post and cap as well as adequacy of base support under the post should be considered. To facilitate joist repair it is recommended that the new member be sized one dimension smaller than the original member. Bridging that is removed should be replaced with solid bridging.

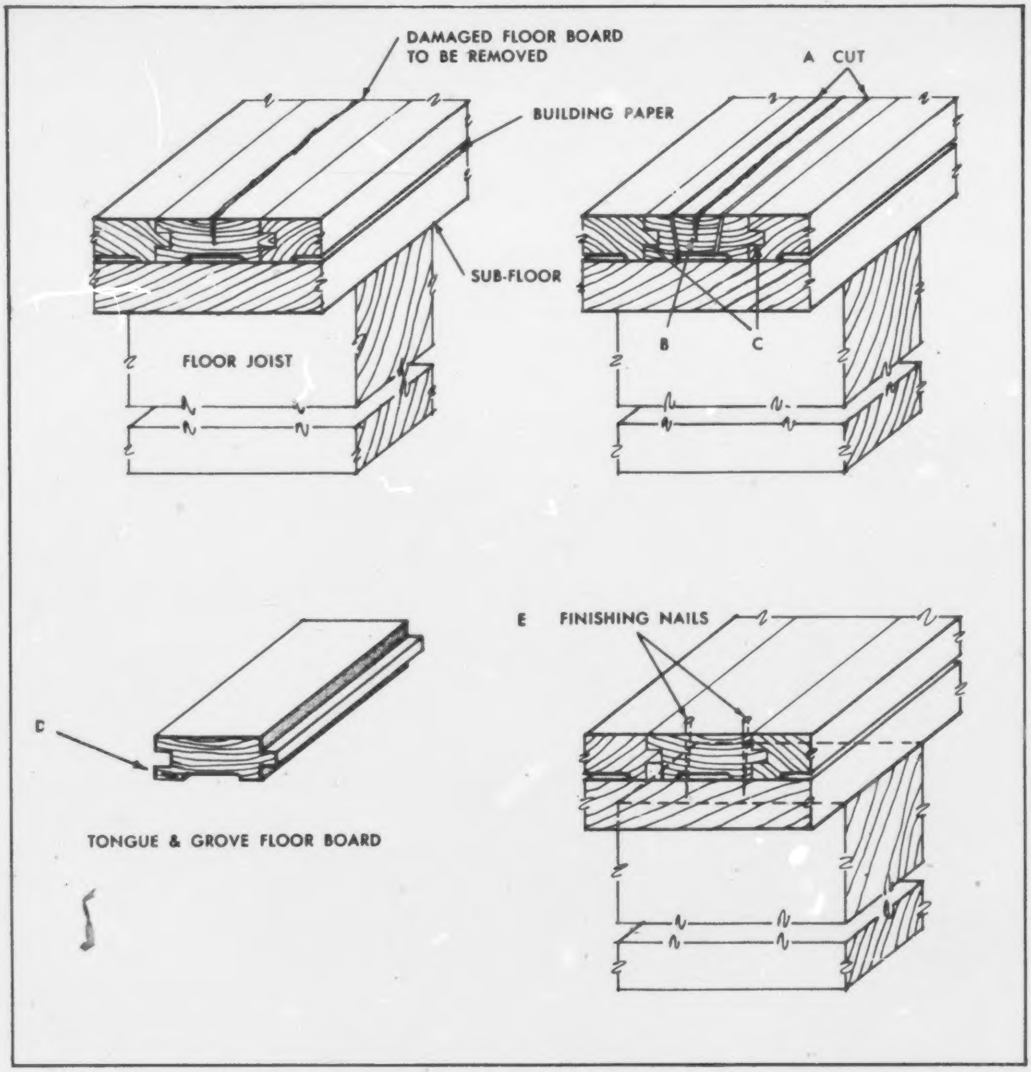
FLOORS AND STAIRS

Floor materials found in shore establishment buildings and structures for various occupancies include wood, concrete, terrazzo, and clay tile. Common floor coverings include asphalt, vinyl tile and linoleum.

Wood Floors

Wood floors should be checked quarterly for loose nails; warped, cupped, or loose boards; raised ends; slivers, cracks, loose knots, or raised nails; and water or other damage from improper cleaning, condensation, and wood decay. If floor damage requires replacement of strips or planks, the following procedures should be observed:

1. Make two longitudinal cuts in the damaged strip or plank. (See fig. 11-5A.)
2. Remove the section between the two cuts by cutting the strip with a chisel at midpoint. (See fig. 11-5B.)
3. Remove the remainder of the damaged strip, taking care not to damage the tongues and grooves of adjoining boards. (See fig. 11-5C.)
4. Remove the lower part of the groove of the new closure strip or plank. (See fig. 11-5D.)
5. Insert the tongue of the closure into the groove of the adjoining board and nail with two 8d annular ring finishing nails through the top surface. When possible, the end joints should be located so the nails will enter the joist. In new closure areas of flooring laid in mastic on concrete, remove the existing mastic and apply new mastic of the type recommended by the flooring manufacturer before installing the new closure.
6. Set exposed nails. (See fig. 11-5E.)
7. Dress the new portion to the level of the adjacent floor by sanding both areas to a continuous, smooth plane.
8. Dry-sweep the area to remove all particles of dust.
9. On open-grained woods, brush on a paste filler. After the filler has partially dried, rub it into the pores of the wood with a circular motion. Wipe the surface lightly to remove any surplus filler. Inadequate filling is indicated by


DAMAGED FLOOR BOARD TO BE REMOVED
A CUT
BUILDING PAPER
SUB-FLOOR
FLOOR JOIST
B
C
D
E FINISHING NAILS
TONGUE & GROVE FLOOR BOARD

117.430

Figure 11-5. —Method of replacing tongue-and-groove flooring.

pockmarks, and results from wiping off too much of the filler or from unusual absorption by the wood. Eliminate such deficiencies by repeating the filler application.

10. Seal and wax the floor.

Concrete Floors

Concrete floors should be inspected annually for dusting, spalling, cracking, and settling. Concrete floors of proper composition, installation, and curing require comparatively little maintenance unless they are exposed to severe abrasion and heavy vehicle loads from industrial traffic; to the deteriorating effect of grease, oils, and food acids such as are encountered in galleys, sculleries, and similar food-preparation spaces; or to caustic soaps and solutions. The corrosive agents in highly acid or alkaline liquids attack concrete floors and cause spalling and pitting. Where trucking is done over concrete floors, as in warehouses, trucks should be fitted with wide-faced wheels; if vehicle abrasion and shock continue to raise maintenance demands, the application of a heavy-duty topping to the concrete should be considered.

CAUTION: Do not paint concrete floors except for functional requirements, such as marking safety lanes or similar areas. Painting for appearance is unjustified and impractical; traffic areas on painted floors will wear first, making the floor unsightly and presenting a difficult cleaning problem.

One of the more common problem areas with concrete floors is the development of unsightly cracks. Cracks in concrete floors may be caused by shrinkage, temperature changes, settlement, or lack of rigidity of supporting beams or other structural members. When such movements are recurrent and can be eliminated only by major structural changes, little can be done except to keep the cracks filled with a mastic material. In many cases comparatively small cracks may be filled with varnish or resin. Although the cracks will remain visible, they will not leak or gather dirt. When the cause of larger cracks has been determined and corrective measures taken to eliminate further cracking, the cracks can be permanently repaired by filling them with non-shrinking cement mortar.

Patching will not permanently correct cracks in slabs on grade caused by vertical movement resulting from exceeding the design load of the slab, inadequacy of the base, or insufficient bearing capacity of the soil. Slab failure under these circumstances can be corrected only by a major maintenance operation, such as mud-jacking. The procedures applicable to the repair of concrete floors are covered in detail in the section of this chapter that deals with the maintenance and repair of waterfront structures.

Terrazzo Floors

Terrazzo floors should be inspected annually for loose or broken segments and damage from improper cleaning. Terrazzo appears to be dense and very hard, but the cement is sensitive to harsh soaps and cleaners, which can cause pitting, roughen the surface, and make the floor permanently susceptible to dusting and dirt trapping. Repairs to a terrazzo floor should be made in accordance with the specification for new floors. Only floor specialists who are capable of the class of workmanship necessary should be entrusted with the work.

Clay Tile Floors

Clay tile floors should be inspected annually for missing, loose, or broken tiles; open joints; and damage from improper cleaning. If floor damage requires replacement of broken or badly stained tiles, or resetting loose tiles, the following procedures should be observed:

1. Remove the damaged or loose tiles.
2. Clean the mortar from the edges of the surrounding tile.
3. Roughen the concrete underbed to provide a good bond for the new setting cement.
4. Dampen the underbed and edges of the surrounding tile and place the setting mortar mixed in the proportion of 1 part Portland cement to 3 parts sand.
5. Set the tile, tamping it to the level of the finished floor.
6. Fill the joints with grout or pointing mortar, matching the color and finish of the joints of the original floor as closely as practicable. If the mortar in the existing joints has deteriorated, cracked, or crumbled, thoroughly clean the joints of all loose mortar and repoint them with grout or pointing mortar as follows:

- Grout joints 1/8 inch or less wide with neat Portland cement grout of the consistency of thick cream.

- Point joints 1/8 inch to 1/4 inch wide with pointing mortar consisting of 1 part Portland cement to 1 part screened sand.

- Point joints wider than 1/4 inch with pointing mortar consisting of 1 part Portland cement to 2 parts screened sand.

7. In locations such as galleys and food preparation areas, where the floor is directly exposed to the effects of corrosion agents, use acid-resistant joint material to fill the joints. The acid-resistant mortars are proprietary products and should be mixed in accordance with the manufacturer's recommendations.

Resilient Floor Coverings

Resilient floor coverings generally used include linoleum, vinyl plastic tile, vinyl asbestos tile, and asphalt tile. Linoleum should be inspected annually for loose seams, buckling, serious indentation, and damage from improper cleaning. Resilient tile should be inspected annually for missing, loose, or broken tiles; open joints; serious indentations; burns; and damage from improper cleaning.

LINOLEUM is repaired by laying out the area along rectangular lines and laying an oversize section of new linoleum over the damaged area. Cut through the two layers simultaneously to insure a tight fit. Remove the damaged section and clean the exposed underfloor of adhesive, dust, and dirt. Replace damaged felt lining. Apply a linoleum adhesive to the exposed surface and fit the new linoleum in place. Roll the area with a linoleum roller and place weights of suitable size on the patch to assure proper adhesion.

RESILIENT TILE is repaired by removing the damaged section and replacing it with new material. Tile is more easily replaced than linoleum because of its smaller size. After removing damaged tile, scrape the exposed area level and clean off all mastic, dust, and dirt. Replace damaged felt lining. Install new tile in suitable cement or mastic in accordance with the manufacturer's recommendations.

Stairways

Stairways should be inspected at least quarterly for adequacy of support and safe condition of components. Stairways should be checked, as appropriate, for cracked, weathered, or rotted wood framing; for settled, cracked, or spalled concrete; and for rusted or loose metal supports. Treads should be inspected for loose or broken tread nosing; excessive wear; paint or tread covering deterioration; and loose, eroded, or slippery tread surfaces. Exterior treads should be sloped (or drilled) so as to drain properly. Handrails should be inspected for loose fastenings and material deterioration. Newel posts and balusters should be checked for looseness and missing parts.

Maintenance on interior wood stairs usually involves treads. Squeaks indicate loose treads, which can be corrected by driving finishing nails through the treads into the riser or carriages, or by removing the molding under the tread overhang, driving wood wedges between the tread and riser, renailing the tread tightly, and replacing the molding. In open string stairs, a tread that is worn but not split or broken may be removed and reversed. Split, broken, or otherwise seriously damaged treads should be replaced with new boards. Housed treads that cannot be removed may be repaired by leveling the worn surface with asphaltic mastic or other suitable plastic materials and covering the tread with a suitable floor covering. Plain and nonslip nosings of steel, brass, bronze, aluminum, and molded hard rubber are commercially available, and should be applied according to the manufacturer's recommendations.

EXTERIOR WALLS

Exterior walls fall into three structural categories: loadbearing walls (carrying structural loads); nonbearing walls (carrying only their own weight); and supported or enclosed walls, sometimes called curtain walls (with their weight supported by structural members).

Exterior walls are made of a wide variety of materials, including wood (shingles, weatherboard siding, plywood); concrete and masonry (brick, concrete or cinder block, reinforced or non-reinforced concrete, structural clay tile, stone, stucco); metal (corrugated iron or steel, aluminum, enamel-coated steel, protected metals); and mineral products (asbestos shingles, asbestos-cement sheets, and glass block).

Wood Exteriors

Wood exteriors should be regularly inspected for damage from wear, accidents, and the elements. They should also be inspected for damage resulting from insect pests. This may be done by tapping the wood with an object. A dull or hollow sound is an indication of damaged wood, which may be the result of insect pests. Painting and surface treatments should be inspected quarterly for deterioration; exteriors should be inspected for loose, warped, cracked, or broken boards or shingles.

Moisture is the most prevalent cause of failure of exterior walls. Stains, paint deterioration, and rot are usual signs of moisture damage. Condensation within and behind walls is a less obvious but equally damaging factor. Insufficient, loose, or displaced nailing produces separations and cracks that admit moisture and reduce the stability of wood walls.

Foundation settlement or displacement may cause misalignment of framing members and consequent damage to walls, including cracks in siding and breaking or displacement of boards or shingles. Make a careful check to determine that existing structural, functional, and material conditions warrant repair to the existing wall rather than complete residing, insulating, or other overall repair or rehabilitation. Where existing situations are satisfactory, replace damaged material with like material. Cut back sufficient areas beyond the damaged part to obtain good jointing and sound nailing. Tighten nails in existing material to be left in place. Be sure that material receiving the new nailed pieces of sections are sound and true. Cover replacement wood with treatment and/or paint matching the original design. When "as-built" plans are available, it is well to examine the original construction detail for assurance that out-of-vision construction and utilities will not be damaged. Warped, split, or curled shingles should be removed with a ripper and replaced in a similar manner as roofing shingles. Panel siding should be periodically checked for looseness and faulty calking. It is usually more economical and satisfactory to replace damaged or deteriorated panels than to attempt patching.

Concrete and Masonry Exteriors

Concrete and masonry exteriors such as concrete block, cinder block, and brick require less frequent maintenance than most outside materials, but certain failures are not uncommon. Exteriors should be inspected quarterly for structural cracks, open mortar joints, settlement, efflorescense, stains, and deterioration of paint or other surface covering.

The most common fault found in block and brick walls is defective mortar joints. Defective mortar joints can be corrected by repointing using the following procedures.

1. Cut out cracked and open mortar joints to a depth of at least 1/2 inch. (Cutting can be done by hand, but if large areas are involved, it is usually cheaper to use power tools.) Take care not to damage brickwork during the cutting process.
2. Remove all dust and loose material with brushes, compressed air, or a water jet. If water is used, no further wetting of the joints may be needed unless the work is delayed.
3. Repair the joints by truck-pointing.
4. Use mortar of about the same density as the original mortar, if determined; otherwise, use a prehydrated mortar mix in the following proportions by volume: 1 part of Portland cement, 1 part of lime putty or hydrated lime, and 6 parts of sand.
5. Be sure the joints are damp, and then apply the mortar by pacing it tightly into the joints in thin layers.
6. Tool the joints to smooth, compact, concave surfaces.

Another problem area which is easily detected during a routine inspection is efflorescense. Efflorescense usually appears as a light powder or crystallization caused by water-soluble salts deposited as water evaporates within the mortar or the masonry unit. Aside from detracting from the appearance of a wall, efflorescence may indicate the penetration of moisture into the wall to an extent that could cause deterioration of interior wall coverings and finishes. Efflorescence may be removed by vigorous and repeated scrubbing with a stiff fiber or wire brush and clean water. An inspection should be made, however, to determine the source of the stain. If efflorescence appears at the edges and not near the center of the masonry unit, the mortar is probably at fault; if it appears near the center of the unit only, the masonry unit is at fault. The most immediate remedy to prevent recurrence of efflorescence is to check causes of excessive moisture that contacts the wall, such as defective flashings, gutters, downspouts, copings, and mortar joints.

Leakage through concrete walls is caused by cracks in the concrete and, in rare cases, porosity of the concrete. As with brick walls the cracks may be caused by foundation settlement, excessive floor loadings, temperature expansion and contraction in structural members, or poor materials and poor workmanship in the original construction. The types of cracks encountered include horizontal movement cracks, vertical and diagonal movement cracks, and shrinkage cracks. An engineering investigation of the causes of structural defects should govern the nature and extent of major repairs.

HORIZONTAL MOVEMENT CRACKS are usually long, wide cracks in the mortar joints that occur along the line of the floor or roof slab, or along the line of lintels over the window. Where these cracks turn the corner of a building, they frequently rack down, as discussed later. Observe figure 11-6, which illustrates a typical horizontal movement crack and racked-down corner.

VERTICAL AND DIAGONAL MOVEMENT CRACKS generally occur near the ends or offsets of buildings. They may also be found extending from a window sill to the lintel or a door or window on a lower floor. They vary from 1/8 to 3/8 of an inch in width and follow the mortar joints, but in some instances they may break through the bricks or other masonry. A diagonal movement crack is illustrated in figure 11-7.

SHRINKAGE CRACKS are the fine hairline cracks that are found in mortar as well as in concrete walls. The most noticeable ones are those running vertically, but a close examination of a section of wall that leaks may also show them in the horizontal or bed joints of brick or block walls.

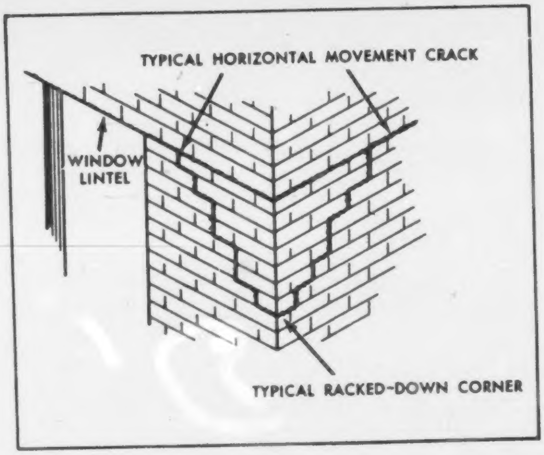


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Figure 11-6. –Horizontal movement and racked-down corner.

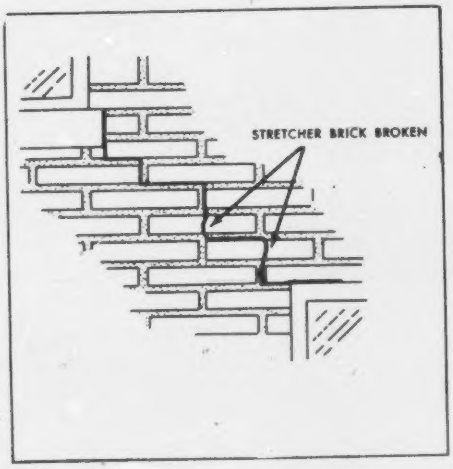

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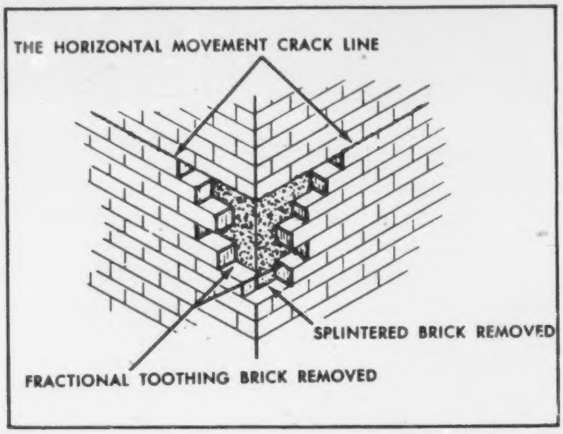
Figure 11-7. –Diagonal movement crack.

RACKED-DOWN corners occur where the horizontal movement cracks along the side and end of a building meet. Frequently the horizontal crack not only continues around the corner but forms part of a diagonal crack that takes a downward direction and meets a similar crack from the other side, forming a V. The bricks inside this V are loosened and must be reset. (Similar procedures may be used for masonry block.)

1. First remove all the bricks inside the V, including any bricks that have been broken. (See fig. 11-8.) This forms irregular sides and helps to hold or key the brick in place.

2. After the bricks are removed, clean the sound bricks and obtain as many new matching ones as are necessary to fill the opening. Relay the bricks in mortar up to and even with the horizontal crack running along the side and end of the building. If all joints are made the same width as the original joints and the mortar tends to match the old mortar, a very presentable job will result. As the bricks are built up, coat the backup bricks with mortar so that the newly laid bricks will be bonded to them.

3. Partly fill with mortar the top joint that is on line with the horizontal crack. This can be done by pushing the mortar into the joint with a narrow pointing trowel. When about half the depth of the joint is filled, fill the remainder with sealing compound. This system of mortaring only half the joint supports the brick above but forms a weak plane along the top of the racked-down areas. If movement takes place, the mortar joint breaks, but the relaid bricks remain in place. The sealing compound keeps the joint watertight.


THE HORIZONTAL MOVEMENT CRACK LINE
SPLINTERED BRICK REMOVED
FRACTIONAL TOOTHING BRICK REMOVED

117.431

Figure 11-8. —Damaged brick removed.

INTERIOR WALLS, PARTITIONS, AND CEILINGS

Interior walls are either plastered or covered with such materials as plasterboard, plywood, wood paneling, tile or glazed faced masonry. Partitions may be of plywood, plasterboard, hard-pressed fiberboard, structural clay tile, gypsum block, metal, and glass. Ceilings are usually plastered or covered with plasterboard or acoustical materials. Some of the major defects to look for when inspecting the more common types of interior walls, partitions, and ceilings are given in the following sections.

Plastered Surfaces

Cracks, holes, and looseness in plastered surfaces are signs of excessive internal or external stresses. They may be caused by poor workmanship, such as improper proportions or application of the plaster, imperfect lathing, and poor atmospheric conditions during plastering; by moisture infiltration or an excess of moist air generated inside a building; or by the settling or other movement of some part of the building frame. External stresses that cause plaster damage should be investigated and corrected before repairs are made to the plastered surfaces themselves.

STRUCTURAL CRACKS.–Structural cracks are easily identified because they are usually large and well defined, extending across the surface and entirely through the plaster. They generally develop during the first year after completion of construction and, in most cases, can be successfully and permanently repaired. However, before repairs are initiated, the cause of the failure should be determined from an engineering standpoint and necessary precautions taken to prevent recurrence of the failure. Structural cracks may extend diagonally from the corners of door and window openings, run vertically in corners where walls join, run horizontally along the junction of walls and ceilings, or occur in walls where two unlike materials join.

To repair a structural crack, use a linoleum knife or chisel to cut out and remove loose material. The crack must be formed to a V-shape to provide adequate keying action by making the surface opening narrower than the bottom of the crack. Care should be exercised to widen the crack only enough to insure a good bond between patching plaster, old plaster, and lath. Expanded metal or wire lath should be cleaned and the mesh opened so that when patching plaster is forced into the opening a good key is formed. Break out the key between wood lath so that a new key can be formed when patching material is forced into place. Thoroughly wet wood lath before applying patching plaster. Brush out all loose material, remove all grease or dirt from surrounding surface areas, and wet the edges of the groove. Press the first coat of patching plaster firmly into place, filling the groove nearly to the surface; allow it to set until nearly dry but not hard; then complete the patch by applying a coat of finished plaster, strike off flush, and trowel smooth. If the edges of the old plaster and the wood lath are not thoroughly wetted, they serve as a wick to draw the water from the fresh plaster, causing it to dry out, remain chalky, and crack around the edges of the patch. In applying the patching plaster, special attention should be given to the edges of the patch to insure a firm, solid bond between old and new plaster.

LOOSE PLASTER.–Loose plaster is indicated by bulging and cracking of large areas of the plaster surface. The extent of loosened plaster can be determined by lightly tapping the surface with a small hammer, with the resultant sounds indicating the extent of the loose area. Loose plaster may result from excessive moisture caused by leaks in the roof, seepage through an exterior wall, plumbing leaks, or heavy condensation. This excessive moisture causes the plaster to become soft, which destroys the bond to the base, causing the plaster to loosen. In some cases the plaster may bulge or sag but continue to hang in this condition quite a long time before falling, being held together only by the hair or fiber in the base coat. Occasionally, moisture causes the fastenings holding the lath to the structural frame to corrode, permitting both the lath and plaster to bulge or sag. Another cause of bulging plaster is the use of incompletely bydrated lime in the plaster mix. In localities where high humidity is prevalent, moisture causes a continued hydration of the lime, which weakens the plaster and destroys the bond between plaster and base. This condition usually occurs in the spring and summer months, starting from the first to third year after plastering and continuing indefinitely.

Before repairing the damaged plaster, it is necessary to locate and eliminate any source of moisture. Temporary repair, to prevent loose plaster from falling until permanent repair can be accomplished, may be made by securing the loose plaster with a section of wallboard nailed securely to the wall or ceiling over the area affected. Nails should be of sufficient length to penetrate through the plaster and obtain a firm bearing in the studs or joists. Repairs of a permanent nature should be made as soon as practicable. Remove all loose plaster around the break, working well back in the surrounding area to a point where solid plaster (well keyed to the lath, which in turn is solidly secured to the structural frames) is obtained. Remove defective lath and replace with suitable plaster backing, such as metal lath or plasterboard, and securely refasten all lath that has become loosened.

DRY WALLS AND PARTITIONS.–Maintenance and repair of interior wall boarding generally requires that nails, screws, and other fasteners be kept in a secure condition. Cracks in plaster-type boards may be repaired similarly to cracks in plaster. Joints in dry-wall construction that fail must be recemented and taped. Broken sections of interior wall-board are generally best corrected by replacement of an entire panel. Wood paneling that develops cracks may be sealed with plastic wood or putty. Broken panels or siding usually are best repaired by replacement of a complete section, panel, or board. When repairs are completed, the repaired area should be finished to match the adjoining area. All fastening, such as nailing, screwing, or gluing, must be at least equal to the "as built" construction. Nonloadbearing partitions should be inspected periodically for marks, dents, scratches, cracks, or other surface damage. Nonload-bearing partitions may be repaired or replaced without regard to the structural frame or ceiling and may be relocated to provide other interior arrangements of space.

DOORS

Exterior doors are more subject to abuse and to weathering than interior doors. In general, though, defects encountered in inspecting both exterior and interior doors are similar.

Doors should be inspected quarterly for the following defects, where applicable: poor fitting, including deteriorated or damaged frames; paint deterioration; material damage, such as cracked or broken glass, split or cracked wood panels, warped or dented metal, and warped or broken screening; and broken or inoperative hardware, such as locks, hinges, and slides. In addition, check all door stops, thresholds and weatherstripping for cracks, looseness and workability, where applicable.

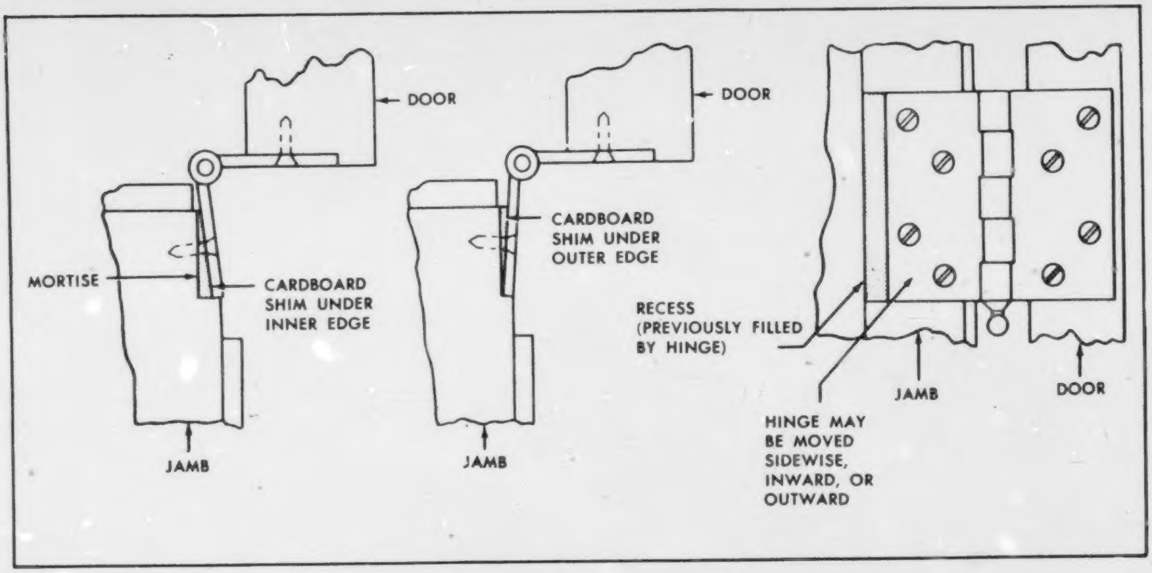
Wood Doors

Mechanical injury to mullions, headers, jambs, or hardware usually causes trouble with LARGE WOOD FRAMED AND BRACED DOORS. Decay, resulting from exposure to weather or shrinkage of door members, also causes distortion or failure. Frequently, the free edge of the door sags and causes the door to bind at the bottom and open at the top. In inspecting these doors, the following checks should be made:

- Examine the jamb opening to see that the hinge and lock sides are plumb and parallel.
- Check the doorhead to see that it is level.
- Check anchorage of the jamb and the hinges.
- Check lock face plates for projection beyond the face of the door.
- Check all members for swelling, shrinking, or warping.

Settling of the foundation or shrinkage and deflection of framing members often causes trouble at door openings. When the greatest settlement is on the hinge side of a door, the door will tend to become floor bound at the lock side. When settlement is greatest on the lock side, the door will bind at the head jamb. As a result, the bolt in the lock will not be in alignment with the strike plate, making it impossible to lock the door securely. Vertical settlement and horizontal deflection will cause the jamb opening to become out of square. On most wood doors the simple correction is to plane as required at either the top or bottom for proper clearance. The following procedures apply when the door itself has shrunk or is warped, swollen, or sagged.

1. When a door shrinks, remove the hinge leaves and install a filler (cardboard or metal shim) at the outer edge of the jamb and hinge mortise. This forces the door closer to the jamb at the lock edge and, provided hinge pins do not bind, the door should then operate satisfactorily. Each hinge should be shimmed equally to prevent the door from becoming hinge bound. When the door has swelled, place shims in the inner edge of the hinge mortise as shown in figure 11-9.
2. Restore a warped door to its normal shape by removing it and laying it flat. Weighing it down may also be necessary. If it is still warped after a reasonable length of time, battens screwed to the door help restore it to true plane. Screw eyes, rods, and turnbuckles help straighten a door by gradually pulling it into place.
3. Install a diagonal batten brace from the top of the lock side to the bottom of the hinge side to repair a sagging door permanently. The diagonal brace must cover the joint between rail and stile and be securely fastened to both members, at top and bottom, and other intermediate rail members. Temporary repair is made by installation of a wire stay brace equipped with turnbuckles and placed diagonally in the reverse direction from a batten brace.
4. Doors or door members may require rebuilding because of neglect or abuse. Remove the door to a flat surface and replace the damaged member. Carpenter's clamps assist in holding door members square while nails or screws are driven.
5. Trim the door when the preceding methods fail to correct the trouble. However, do not cut doors immediately following rain or damp


DOOR
DOOR
MORTISE
CARDBOARD SHIM UNDER INNER EDGE
CARDBOARD SHIM UNDER OUTER EDGE
RECESS (PREVIOUSLY FILLED BY HINGE)
JAMB
JAMB
JAMB
DOOR
HINGE MAY BE MOVED SIDEWISE, INWARD, OR OUTWARD

117.432

Figure 11-9. —Hinge adjustment for binding or sticking doors.

weather. When dry, the door may fit too loosely.

Failures in PANEL DOORS are similar to those in large wood doors. In addition, panel doors are subject to binding at the hinge edge, as well as friction between the dead bolt and strike plate or between the latch bolt and strike plate.

Metal Doors

Metal doors, commonly used in warehouses, hangars, stockrooms, galleys, and other areas where hard service or other operations require them, are of various types: metal clad, hollow metal, and solid metal, with variations including interchangeable glass and screen panels.

Because most metal doors and fittings are shop designed and fabricated, it can be assumed that they will maintain their shape and mechanical operating ability provided hinges, locks, and other fittings remain secure in their fastenings. This is accomplished by checking screens, nuts and bolts, and special fasteners and operating devices regularly and keeping them tight and in good order. Building settlement, mechanical failure, and collision may require investigation and corrective measures for a basic cause of misalignment in the structure framing itself. Frames must be plumb and corners square so the door fits its opening with proper clearances. Weatherproofing and calking must be maintained in a workmanlike manner. Mechanically operated doors must be removed and straightened, repaired, or replaced. Repair material and finishing should match the existing material. Shop repair of metal doors should meet acceptable standards for welding, riveting, and sightliness. Replacement of surface metal on fireproof metal clad wood doors must be weather-tight and of material of the same gage as originally provided. Service doors in galleys, stockrooms, and other areas where personnel pass in and out frequently with arms loaded should be provided with kickplates and with bumper protection to prevent slamming against walls.

WINDOWS

Both wood and metal windows are found in structures at Navy activities, and the inspector should be alert to detect any defects present in either type. Windows should be inspected quarterly, as appropriate, for loose-fitting or damaged frames; ill-fitting or broken sash; cracked or broken glass; deteriorated putty or calking; broken or worn sash balances, and missing or broken hardware.

Window failures may result from various causes, the most common of which is weathering, which causes loss of putty, paint, and calking. This leads to subsequent deterioration and rotting in wood windows and rusting in metal windows. If atmospheric conditions cause ordinary putty to deteriorate quickly, plastic glazing compound should be substituted. Calking around window frames must be maintained in good order to prevent leakage of moisture and air (see fig. 11-10). Rust spots on metal sash and frames should be wire brushed or sanded, cleaned with a rag saturated with mineral spirits, and then painted. Problems of alignment caused by building settlement must be adjusted in conjunction with overall corrective measures, which may involve stabilizing the foundation and framing.

ROOFS

Roof structures can be classified according to their shapes and structural limitations. They can be flat, pitched, sloped (such as shed or lean-to types), curved such as provided by bow-string trusses or circular arches, or mansard, which is a combination of a steep pitched and a shallow pitched roof. Roofs that are supported on exterior walls and at a ridge or bearing at some intermediate point are usually referred to as frame roofs. Those that are truss or arch supported only at the exterior walls or other trusses or columns are referred to as trussed roofs. Rafters are the structural members of a frame roof.

Frame Roofs

Rafters are generally more accessible to inspection than other structural members of a frame building. They are usually uncovered on the underside, so defects and failures can be visually detected. Warped, twisted, or broken

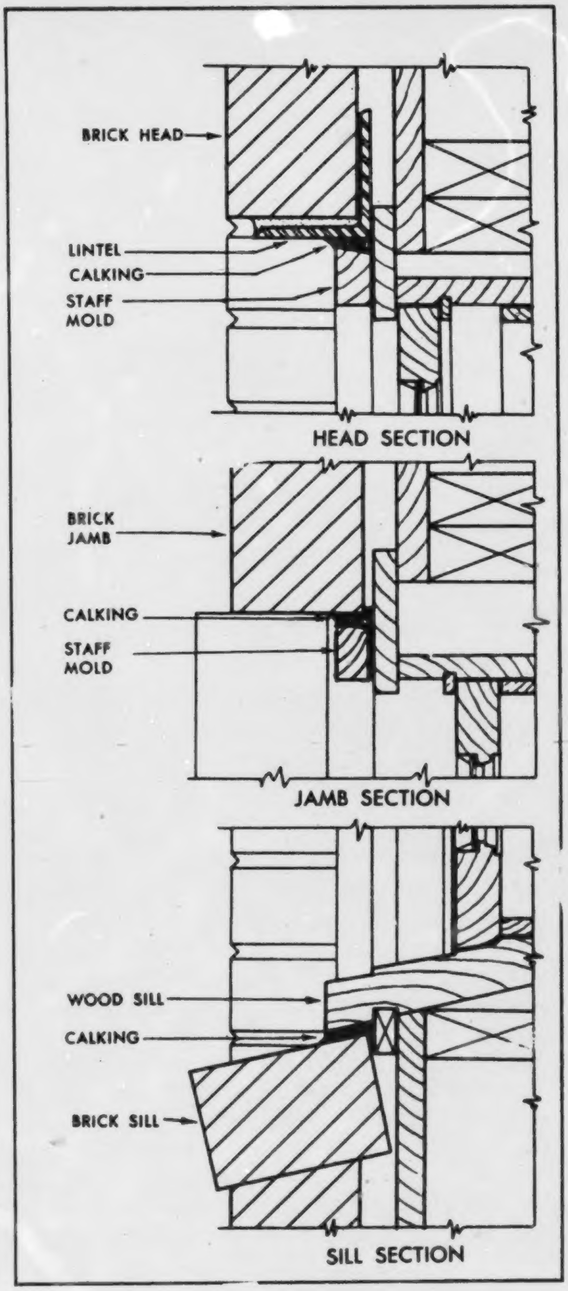


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Figure 11-10. —Required calking around wood window frame.

rafters can be replaced or, if the roof surface is sound, they may be repaired. Warped and twisted rafters can be straightened by the addition of solid bridging and bracing; broken pieces can be scabbed without harm to the roof covering. Rafters, sheathing, and other roof-framing members that are damaged by decay must be replaced. A prevalent cause of extensive roof maintenance is failure of the roof covering. Leaky roofs no longer protect the framing, thus allowing weathering and eventual decay.

Trussed Roofs

Trusses should be inspected at least once a year to determine if there is:

- Failure in upper and lower chord or web members.
- Bowing of overstressed compression members.
- Evident separation of joints caused by shrinkage.
- Development of splits along lines of bolts.
- Development of splits in ends of web members and chord splices.
- Pronounced sagging of truss.

Normally, if an actual failure has occurred in a chord member, that member should be replaced. To do this, the truss should be shored at the panel points along the bottom chord and the damaged member removed. Using the damaged member as a template, the new member can be fabricated and installed. The replacements should be of the same material as the truss and of the same moisture content, if possible. To replace any truss member is usually a costly operation; unless the building is for permanent use, the member should be repaired or augmented rather than replaced.

Checking and splitting are normal reactions in most timber as it dries out, the checking and splitting being more pronounced when unseasoned lumber is used. If the split passes through the bolt holes and continues beyond into the member, it will require attention. The recommended remedy for such splitting and checking is the installation of STITCH BOLTS. Figure 11-11 illustrates the use of stitch bolts in repairing scabs in which end splits have developed; also shown is stitch bolt repair to wood columns in which splitting and deep checking along the grain have occurred. The bolts used for this purpose are 1/2-inch bolts, threaded on both ends. In repairing scabs, half-inch holes are drilled 2 or 4 inches from the end of the split member and perpendicular to the axis of the member. The bolt is then inserted and a 2-inch square cut washer placed at each end and the nuts tightened. It is advisable to install the stitch bolts prior to tightening the bolted connection.

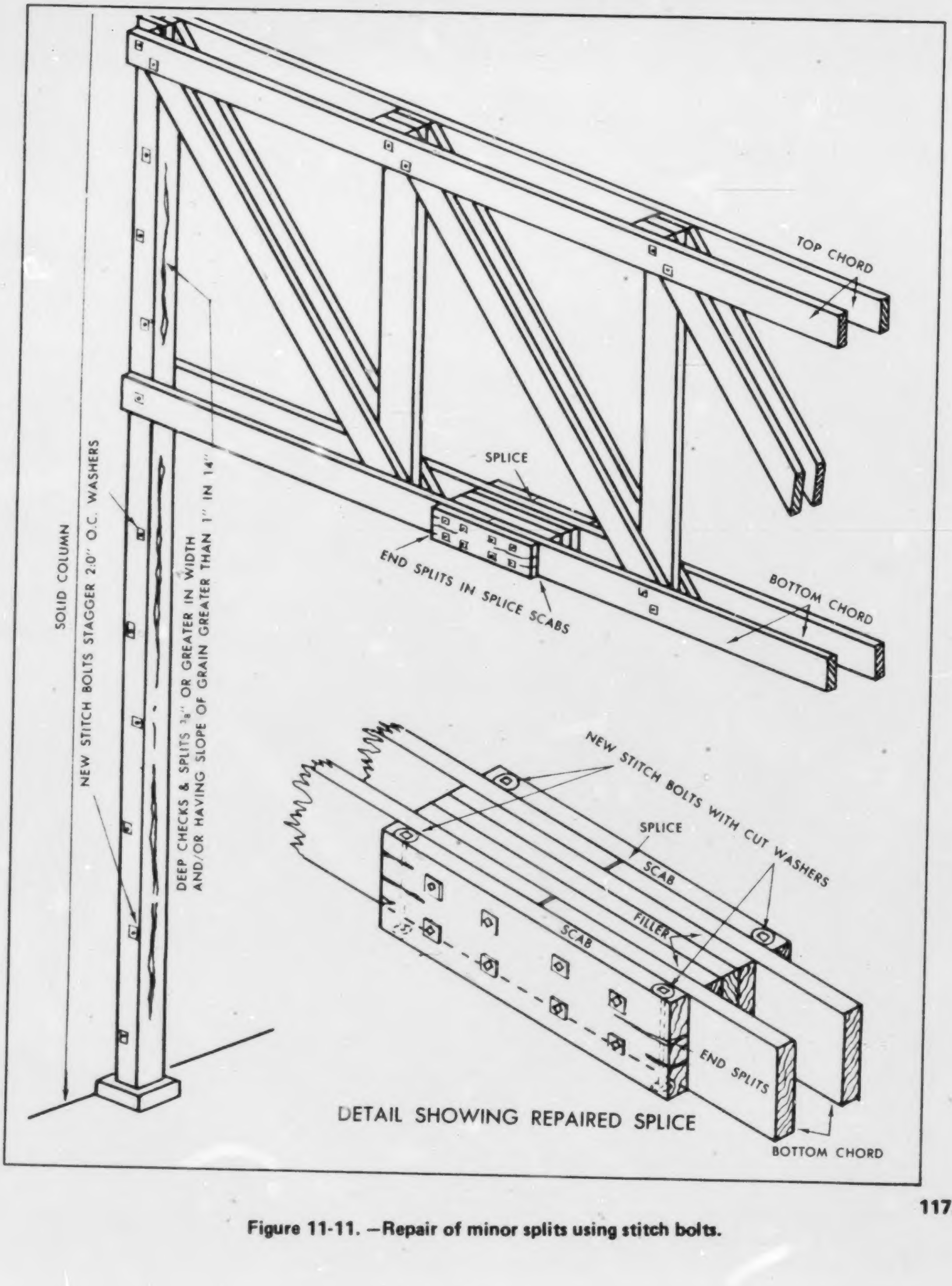
ROOFING

Failure to inspect, recognize and correct minor defects and deterioration in its earliest stages, that is, the lack of proper preventive maintenance, is probably the greatest cause of premature roof failure. All roofing materials deteriorate on exposure to weather, the rate of deterioration being affected largely by the kind of material involved and the conditions of exposure.

In inspecting structures, you will probably inspect different types of roofing, such as built-up, asphalt-shingle, cement-asbestos, metal, tile, and so on. No attempt is made here to cover in detail the many types of roofing materials and their component accessories produced by numerous manufacturers, but rather to discuss, in general terms, the inspection and preventive maintenance procedures peculiar to built-up and metal roofing.

Built-up Roofing

Built-up roofing is exactly what the name implies; a membrane built up on the job from alternate layers of bituminous-saturated felt and bitumen. The bitumen used to saturate the felt and employed as a plying cement and coating for the saturated felts may be asphalt or coal-tar pitch. These can usually be distinguished by their odors. Asphalt has a distinctly oily odor and coal-tar pitch a somewhat pungent odor. These odors can be detected best with freshly broken specimens or from fumes of specimens that have been ignited and freshly extinguished.


TOP CHORD
SPLICE
END SPLITS IN SPLICE SCABS
BOTTOM CHORD
SOLID COLUMN
NEW STITCH BOLTS STAGGER 2'0" O.C. WASHERS
DEEP CHECKS & SPLITS 3/8" OR GREATER IN WIDTH AND/OR HAVING SLOPE OF GRAIN GREATER THAN 1" IN 14"
NEW STITCH BOLTS WITH CUT WASHERS
SPLICE
SCAB
FILLER
SCAB
END SPLITS
DETAIL SHOWING REPAIRED SPLICE
BOTTOM CHORD

117.434

Figure 11-11. —Repair of minor splits using stitch bolts.

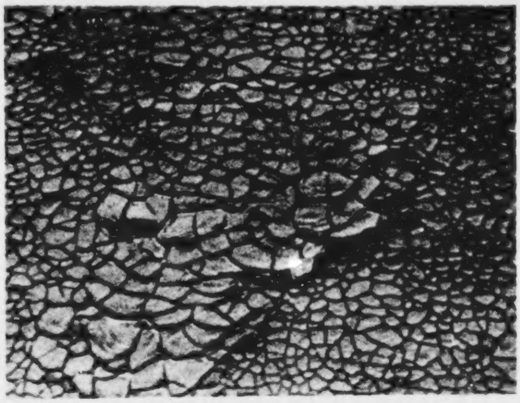
It is important that you determine the type of the existing bituminous material before making or recommending repairs as asphalt and coal-tar pitch are not compatible and contact between the two should be avoided. If in doubt, a solubility test should be performed.

The SOLUBILITY TEST is performed by pouring white gasoline into a container to which is added a small amount of unknown bituminous material. That amount which will stick to the head of a nail will be sufficient. The mixture is then agitated to determine the solubility of the unknown material. If the material mixes readily, giving a homogenous mixture, it is an asphalt cement. If it gives a mixture with stringy particles in suspension, it is a tar, as tars are insoluble. If the unknown material is not readily soluble but forms black globules (balls), it is an asphalt emulsion. Built-up roofing should be inspected semiannually for cracking, alligatoring, low spots and water ponding; exposed bituminous coatings; and exposed, disintegrated, blistered, curled, or buckled felts.

CRACKING AND ALLIGATORING.–Smooth-surfaced, asphalt built-up roofs on which the surface mopping is relatively thin usually show definite alligatoring of the surface coating within 3 to 5 years. Alligatoring is always most severe where the asphalt coating is thickest. If allowed to proceed, alligatoring will develop into cracking as shown in figure 11-12. Once the surface coating is cracked, water penetrates the membrane and the roof deteriorates rapidly. Consequently, maintenance is necessary to prevent cracking.

The type and extent of maintenance should depend on the future use of the structure. On smooth-surfaced organic felt roofs of relatively brief expected use (4 years or less), remove all dust and dirt by sweeping, vacuuming, or air blasting and apply a thin coat of asphalt primer. After the primer is dry, one of two coating materials (asphalt or asphalt emulsion) may be applied by brushing or spraying at a rate of 3 gallons per square (100 square feet).

NOTE: Information as to the standards for primers and bituminous materials used in built-up roofing maintenance is contained in NAVFAC Specification 7Y.

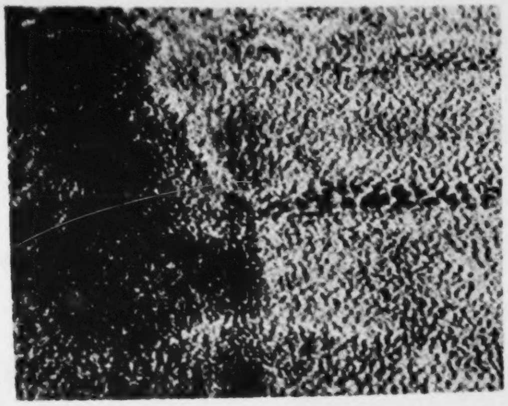


133.239

Figure 11-12. –Alligatoring and cracking.

If the asphalt coating is alligatored but not cracked and the felts are not exposed, the primer may be omitted. If an asphalt emulsion coating is to be applied to such surfaces, dust and dirt may be washed off with a stream of water from a hose. The emulsion can be applied to a damp, but not a wet, surface.

On organic (rag) felt roofs intended for prolonged use (over 4 years) the cleaning and priming requirements are the same as for roofs of relatively brief expected use. After the primer has dried, apply one coat of asphalt emulsion at a rate of 2 gallons per square. Immediately after applying the emulsion, while it is still wet, embed strips of fibrous glass mesh (woven or nonwoven) in the emulsion, lapping the strips two inches. While the first coat of emulsion is still wet, apply a second coat of emulsion at a rate of one gallon per square over the fibrous glass strips. After the second coat of emulsion has set firmly, apply a final coat of emulsion at a rate of 2 gallons per square. If the asphalt surface is alligatored but not cracked and the felts are not exposed, the primer may be omitted. Figure 11-13 illustrates the benefit obtained by the use of the fibrous glass strips. The section on the left shows an area of an alligatored roof that was coated only with asphalt emulsion. The section on the right was coated with the same emulsion reinforced with fibrous glass strips. Both were exposed 2-1/2 years.



117.435
Figure 11-13. —Comparison of cold coating (asphalt emulsion) with and without glass membrane.

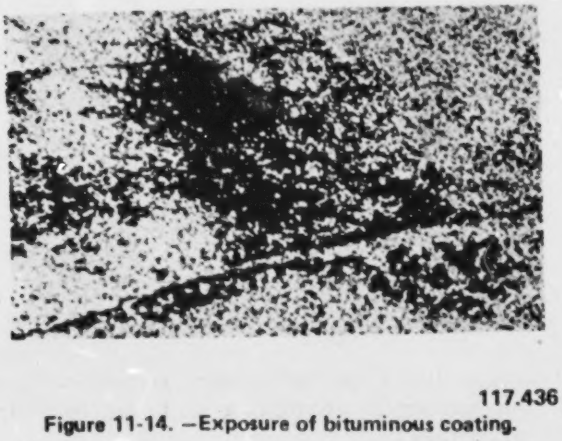
EXPOSED BITUMINOUS COATING.–When the bituminous coating on a mineral-surfaced built-up roof is exposed as shown in figure 11-14, brush loose gravel or slag from the bare area. Cover the bare area with hot bitumen poured at a rate of 70 pounds per square and embed fresh gravel or slag. Old gravel or slag may be reapplied when the dirt and dust have been screened from it.

EXPOSED FELTS.–Smooth-surfaced, asbestos-felt built-up roofs may be surfaced originally with hot asphalt or with a cold-applied asphalt emulsion. After four or five years of exposure (sometimes earlier with cold-applied coatings), light gray or even white areas appear, indicating that the felts are partly exposed. Because the asbestos felts are constructed mainly of inorganic materials, exposure to the weather is much less serious than with organic felts. For an expected use of not more than 4 years, no treatment is necessary. Manufacturers of asbestos felts usually do not recommend recoating asbestos-felt roofs at any time. However, recoating with asphalt emulsion at a rate of 3 gallons per square, at intervals of four or five years, will prolong their usefulness indefinitely.

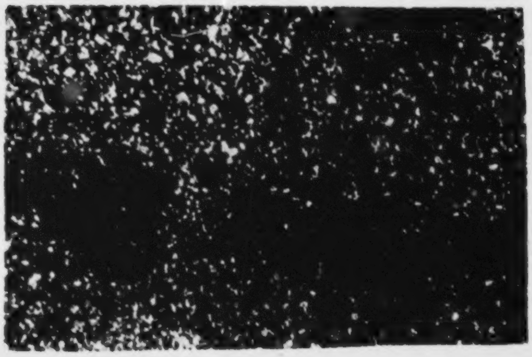
On mineral-surfaced built-up roofs, exposed felts are repaired by first removing all dust and dirt from the exposed area and, in the case of asphalt roofs, applying one thin coat of asphalt primer. When the primer is dry, treat as described for exposed bituminous coating. Coal-tar pitch roofs are treated similarly except that no primer is required before the coal-tar pitch is applied.

On organic felt smooth-surfaced built-up roofs, repairs to exposed felts should be made as described for those on mineral-surfaced roofs except that 20 or 25 pounds of asphalt should be mopped per square and the mineral surfacing omitted.

DISINTEGRATED FELTS.--To repair felts that have been exposed and partially disintegrated (fig. 11-15), scrape off all surfacing



117.436
Figure 11-14. —Exposure of bituminous coating.



117.437
Figure 11-15. —Exposed felts that are partially disintegrated.

material to at least 2-1/2 feet beyond the area of disintegrated felts. Remove disintegrated felt layers and replace them with new 15-pound bituminous-saturated felts of approximately the same size, mopped in place with hot bitumen. Apply at least two additional layers of 15-pound saturated felt, mopped on with hot bitumen and extending at least 12 inches beyond the area covered by the replacement felts. Apply a pouring of hot bitumen to the repaired area at a rate of 70 pounds per square and into it, while hot, embed fresh gravel or slag.

As mentioned earlier, asphalt and coal-tar pitch are not compatible. Asphalt and asphalt-saturated felt should always be used in the maintenance of asphalt built-up roofs, and coal-tar pitch and coal-tar saturated felt in the maintenance of coal-tar pitch built-up roofs.

Metal Roofing

Copper, terne (tin), galvanized steel, and aluminum roofing should be inspected semi-annually for holes, looseness, punctures, broken seams, inadequate side and end laps, inadequate expansion joints, rust or corrosion, and damage resulting from contact of dissimilar metals. Because the different metal roofing materials normally require different preventive maintenance, they are considered separately herein. However, copper, terne, and aluminum roofs have one thing in common. When they have been well applied and adequately maintained, reroofing is seldom required.

COPPER ROOFING.–The most common cause of failure in copper roofs is the failure to provide adequately for expansion and contraction. Broken soldered seams and breaks in the metal at points other than the seams indicate inadequate provision for expansion and contraction. When broken soldered seams on flat seam roofs indicate inadequate provision for expansion and contraction, new expansion joints sufficient to provide a joint at intervals of not more than 10 feet in each direction should be installed. If soldered horizontal seams on batten- and standing-seam roofs are broken, loose lock seams that will permit movement of the sheets should be installed at those points.

Small holes in copper roofing can be repaired with a drop of solder. In soldering copper, scrape with a sharp instrument or emery cloth until bright metal shows on any surface that is to contact the solder. Then apply flux and tin the surface with a thin coating of solder. It is a very poor practice to coat copper roofing, flashings, and gutters with an asphaltic mastic coating for the repair of small holes and breaks. Larger breaks or punctures, not caused by inadequate provision for expansion and contraction, may be repaired by soldering a piece of copper over the break or puncture.

TERNE ROOFING.–The most frequent cause of failure in terne roofs is the lack of maintenance painting. The frequency of painting will vary with different conditions of exposure, but painting should never be put off until rust appears nor should thick coatings of paint be built up by too frequent painting.

Many leaks in terne roofing are caused by faulty seams. Formed seams that show evidence of leaking should be re-formed or calked with a plastic calking material. Broken soldered seams, small holes, and larger breaks are repaired in accordance with the procedures used to repair similar defects in copper roofs.

GALVANIZED STEEL ROOFING.–Corrugated galvanized roofing is the lowest in cost of all types of metal roofing and, when properly applied and maintained, it renders satisfactory service. Because it is the type of galvanized roofing used most frequently on warehouses and sheds, it is taken as representative of the galvanized metal roofings. The most frequent causes of failure in galvanized roofs are improper application and lack of maintenance painting. Leaks at seams and fasteners are evidence of improper application.

Inadequate laps in galvanized steel roofing may be repaired by calking or, in severe cases where calking is impracticable, by covering the laps with a membrane such as asphalt saturated cotton fabric or lightweight, smooth-surfaced roll roofing in accordance with the following procedures.

1. Apply an asphalt roof coating to the seams in strips approximately 6 inches wide. Use approximately 1 gallon of coating material to 80 lineal feet of seam.

2. Cut the roll roofing or saturated fabric into 4-inch strips approximately 12 feet long. Embed the membrane strip in the asphalt roof coating, pressing it firmly into the coating until it lies flat without wrinkles or buckles; the center of the strip must be directly over the exposed edge of the roofing.

3. Then apply another coating directly over the membrane strip so that the membrane is completely covered and the first and second coatings are continuous.

Roof coating materials vary considerably in consistency, composition, and setting time. In some cases, it may be desirable to allow the first coating to become tacky before applying the membrane material, or to allow the first coating with the membrane embedded in it to remain for some time before applying the second coating.

It should be realized that repairs of this kind cannot be expected to last as long as the galvanized sheets. Seams treated by this method should be maintained by recoating them periodically with an asphalt coating of the type used in the original treatment. In warm humid locations, recoating will probably be necessary after 18 months to 2 years; in other locations, after 2-1/2 to 3 years.

ALUMINUM ROOFING.–Aluminum roofing, properly applied, does not normally require maintenance. Failures in aluminum roofing that result from improper application are essentially the same as those encountered with galvanized steel roofing and are repaired similarly.

Flashing

Because numerous failures attributed to the roofing material are frequently flashing failures, these areas should be the first to be inspected when leaks in a structure are reported. A good procedure to follow is to first make a careful inspection of the roofing material near the flashings for signs of moisture. Punctures, broken laps or seams, separation of flashing from vertical surfaces, and deterioration from weather are causes of failure.

If a separation occurs between the base flashing and a wall, such as shown in figure 11-16, refasten the base flashing to the vertical surface by nailing or cementing. Recoat with a plastic flashing cement and replace appropriate counter flashing.

Leaks sometimes occur around vent flashing. The majority of vents are constructed of metal and, consequently, are subject to expansion and contraction. For this reason, it is poor practice to attempt to flash up the sides of such projections as this type of flashing is subject to early failure. Vents are usually of two types, namely, the flat flange vent and the curb flange vent. The former is the most common. The flat flange vent is placed directly upon the last ply of roofing whereas the curb vent is constructed to fit over a wooden or concrete curb. When exposed nails that hold a flashing flange to a roof work loose as shown in figure 11-17, raise the flashing flange high enough to force plastic cement beneath it, and redrive the loose nails. Apply two plies of felt or fabric cemented to each other and to the flange with asphalt, pitch, or plastic cement. The outer edge of the first ply

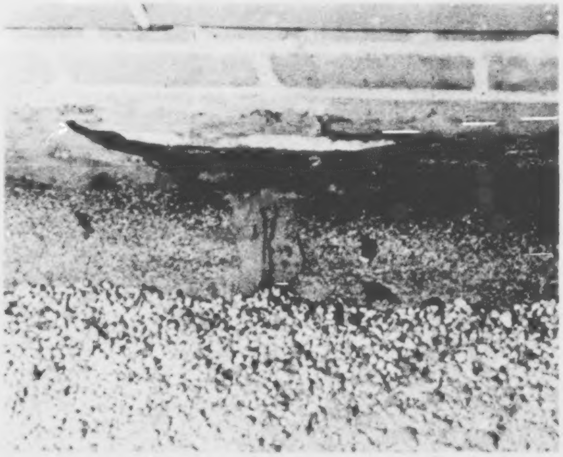


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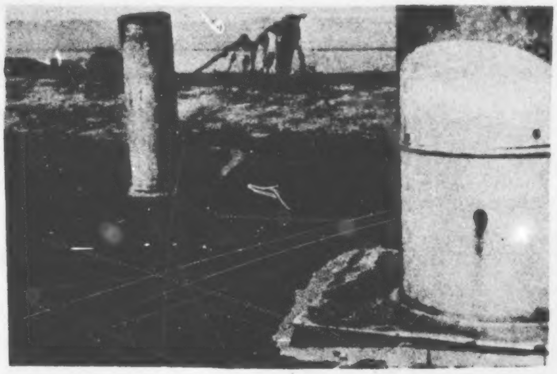
Figure 11-16. —Leaks caused by entrance of water at defective flashings—sometimes attributed to failure of roof membrane.



117.439
Figure 11-17. –Separation of metal flashing flange from roof–caused by exposed nails that have worked loose.

of felt or fabric should extend not less than 3 inches beyond the flange and that of the second ply of felt or fabric not less than 6 inches. Apply finished surfacing similar to existing roof surfacing.

Drainage Systems

The primary function of a drainage system is to remove water from a roof as quickly as possible and to prevent the accumulation of water on the roof. It is important that drainage areas be kept free from debris that will interfere with proper drainage. Many roof failures can be traced to inadequately maintained drainage systems. If during a semiannual roof inspection you notice the accumulation of debris in gutters and around drains, take action to ensure that all such debris is removed so as to prevent subsequent roof failure.

PAINTED SURFACES

Paints are not indestructible. Even properly selected protective coatings properly applied on well prepared surfaces will gradually deteriorate and eventually fail. The rate of deterioration under such conditions, however, is slower than when improper painting operations are carried out. Inspectors and personnel responsible for maintenance painting must be familiar with the signs of various stages of deterioration in order to establish an effective and efficient system of inspection and programmed painting. Repainting at the proper times avoids the problems resulting from painting either too soon or too late. Painting scheduled before it is necessary is uneconomical–and eventually results in a heavy film buildup leading to abnormal deterioration of the paint system. Painting scheduled too late results in costly surface preparation and may be responsible for damage to the structure, which then may require expensive repairs.

All painted surfaces should be inspected at definite intervals. They should be inspected semiannually in exterior and corrosive environments, in areas where heavy traffic may cause rapid wear (floor finishes) and in areas when sanitation is important. Other areas should be inspected annually. The inspector should observe their condition with reference to type and stage of deterioration, and make recommendations for spot-painting, repainting, or more frequent inspection. The frequency of repainting can be determined by periodic inspection of all coatings. It is important to check on a systematic basis so that painting can be scheduled in advance, at a time when the coating is thin enough yet has not degraded to the point of disintegration. Thus, little surface preparation will be required and only one or two coats of paint may be necessary.

Deterioration

Paints which are exposed outdoors normally proceed through two stages of deterioration; generally, a change in appearance followed by a gradual degradation. If repainting is not done in time, disintegration of the paint then takes place followed ultimately by deterioration of the substrate (basic surface). Interior coatings generally change slowly in appearance with time but do not usually degrade to any significant extent otherwise.

CHANGE IN APPEARANCE.–The first stage of deterioration shows up as a change in appearance of the coating with no significant effect on its protective qualities. This change in appearance may result from soiling, fading, or flattening depending on the type and color of the paint used and the conditions of exposure.

DEGRADATION.–The second stage of normal deterioration occurs after continued exposure. The coating begins to break down, first at the surface, then, unless repainted, gradually through the coating and down to the substrate. There are two types of degradation which may take place–chalking, and checking and cracking; the degree of either depends on the type of paint and the severity of exposure. When large areas of substrate become exposed, the coating has reached the point of complete deterioration and is in a state of neglect. Such surfaces require extensive and difficult preparation before repainting. All of the old coating may have to be removed to be sure that it does not create problems by continuing to lose adhesion, taking the new coating with it. Furthermore, complete priming of the exposed substrate will also be required, thus adding to cost and time. Continued neglect may also lead to deterioration of the structure resulting in expensive repairs in addition to painting costs.

It is assumed that, through study and experience, you are familiar with the defects resulting from the various stages of deterioration mentioned above and can readily identify them. Therefore, the defects are not described here.

WATERFRONT STRUCTURES

As with buildings, the maintenance inspection of waterfront structures should be designed to include (1) the prompt detection of deficiencies or damages, and (2) the expeditious performance of repairs, consistent with requirements, in an economical and workmanlike manner. Deterioration of waterfront structures is due to the destructive forces to which they are exposed, such as:

1. Attack by marine organisms.
2. Rust, corrosion, and decay.
3. Mechanical damage, including the impact and pressure of ships, and the abrasive action of sand and debris.
4. Wave action and erosion.

In order to determine the extent of maintenance and repair work required, an inspection should be made annually of all basic structures (piers, wharves, quaywalls, bulkheads, retaining walls) and semiannually for fenders and movable equipment, such as brows and camels. More frequent inspections than these prescribed may be necessary under certain circumstances, such as tidal waves, high tides, earthquakes, and action by destructive forces of nature. Inspections may be made from the structures, from a boat or afloat, or from below the waterline by divers. Cameras are often employed in visual inspections.

Some of the major defects that can be seen by visual inspection are:

- Spalls, cracks, and breaks in concrete work.
- Rusting of structural steel, and exposed reinforcing steel in concrete.
- Decay in wood.
- Mechanical damage resulting in broken or bent structural members.
- Damage to wood piling by marine organisms.
- Damage by wave action and water erosion, including the washing out of fill through defective sheet piling.
- Shrinkage of timbers around bolts and cracks around loose bolts allowing water to enter. These conditions are usually found in pier curb rails, stringers, wales, pile caps, and other members above the tidal range.
- Deterioration of decking.
- Loose spikes and bolts; worn, cracked or broken rails, and deteriorated ties.
- Deterioration of service lines, terminal boxes, outlets, broken brackets, loose insulation, corroded piping, and broken seals.

CONCEALED DAMAGES are often overlooked in a visual inspection. It is often necessary to resort to special methods or tests. When underwater damage is suspected, divers are generally required. Some of the methods employed to discover concealed damages are tapping with a hammer and probing with a chisel, screwdriver, or sharp-pointed instrument to detect deterioration or decay will usually indicate whether further examination is necessary. Any evidence of damage or deterioration affecting the structural stability of any structure should be the subject of an immediate engineering study.

Waterfront structures, for the most part, contain one or more of the following materials; concrete, metal, wood, stone, earth, or masonry units. Because of this, the following sections describe the maintenance and repair procedures peculiar to each of these materials in general and with specific procedures when applicable to their use in certain structures.

CONCRETE

Good Portland cement concrete is a fairly permanent construction material, but local conditions can produce defects that require corrective measures. The BU should be familiar with common types of defects that occur in concrete and know what measures to take to correct these defects.

Repairing Concrete

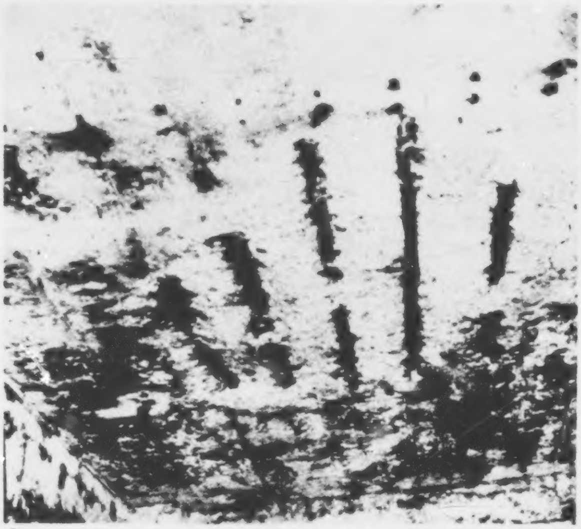
When concrete that covers reinforcing steel is deteriorated, spalled, or cracked, the reinforcing steel begins to rust and repairs should be made promptly to avoid excessive damage. All loosened materials must be removed and the concrete cut back to sound material. Cut the areas to be patched a minimum of one inch and at right angles to the surface. If the reinforcing steel is seriously damaged by rust, cut the concrete back far enough to replace the damaged steel by new reinforcing. New reinforcing bar should match the original bars in size and grade of steel and should be lapped at each end for a length of not less than 30 diameters of the original bars or as directed by higher authority. The new bars must be securely wired or welded to the old before patching. Exposed reinforcing steel that is not seriously damaged by rust should be cleaned by brushing or sandblasting so as to make a firm bond with the new concrete. Reinforcing steel should be covered by a minimum of three inches of concrete if at all possible.

Superstructure Repairs

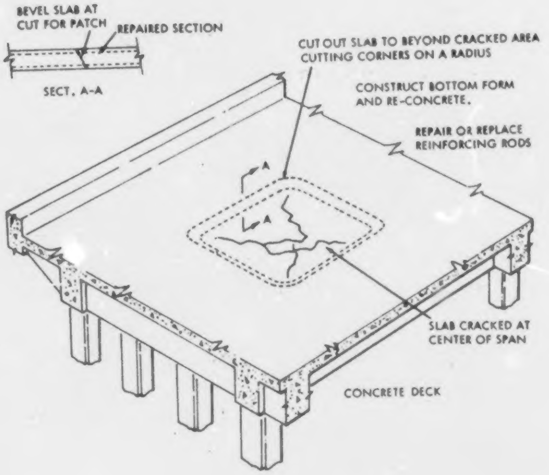
Repairs to superstructures will include filling surface cracks, replacing structural members, cutting and filling expansion joints, and resurfacing decks.

SURFACE CRACKS.–Surface cracks that are not structural defects must be promptly filled to avoid the entrance of water. Thoroughly clean the crack with a high-pressure water jet to remove all foreign matter. Edges of the crack should be moistened but not wet. Fill the crack with a thin grout of cement and water, using a brush if necessary to push the grout in the crack. For wider cracks, use a mortar of cement, sand, and water instead of cement grout. If such cracks are of insufficient width to permit placement of filler material, they should be cut out prior to cleaning. After filling the crack, cover with burlap or sand and keep the covering moist for at least three days. Asphalt, tar, and certain other materials may also be used with satisfactory results for sealing random cracks in concrete decks and curbs.

PATCHING AND REPLACEMENT.–Forms are usually required except for minor patches on top of a slab and for pressure-applied concrete. Forms may be of pipe, sheet metal, or wood and either left in place or stripped. They should be strong, well-braced and, if to be stripped, designed so they can be removed without damaging the concrete. Pressure-applied concrete is generally used to repair spalling on the underside of a deck or beam. (See figs. 11-18 and 11-19.) Cut back the spalled area to sound concrete, and replace reinforcement as described earlier. Then repair or rebuild to original section with pressure-applied concrete. Slabs or other structural members that are broken or severely damaged must be replaced. The assistance of qualified engineers should be obtained to analyze such cases, to determine the cause of failure, and to furnish an adequate design of

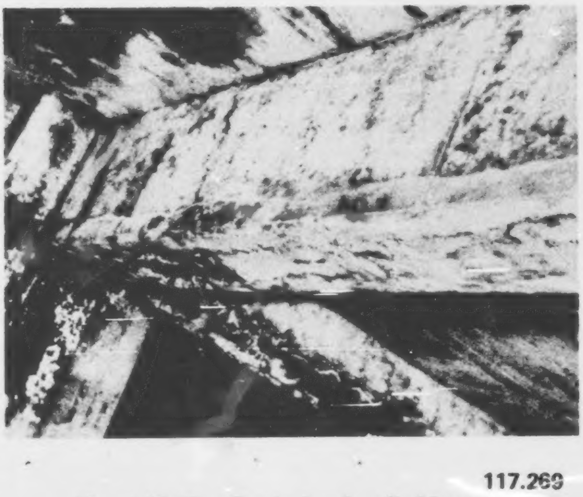


117.268
Figure 11-18. —Repair of spalling.

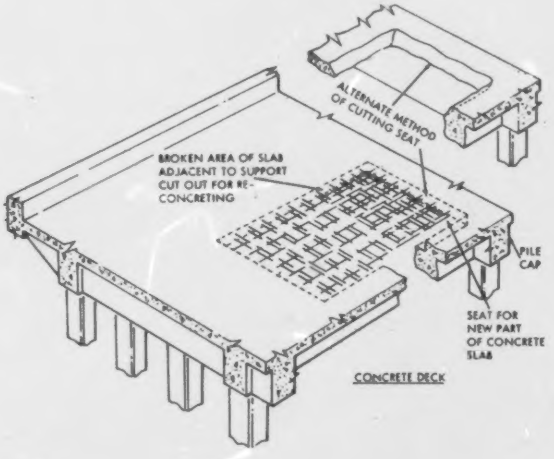

BEVEL SLAB AT CUT FOR PATCH
REPAIRED SECTION
SECT. A-A
CUT OUT SLAB TO BEYOND CRACKED AREA CUTTING CORNERS ON A RADIUS
CONSTRUCT BOTTOM FORM AND RE-CONCRETE.
REPAIR OR REPLACE REINFORCING RODS
A
A
SLAB CRACKED AT CENTER OF SPAN
CONCRETE DECK

117.270
Figure 11-20. —Repair of deck at center of span.

replacement members. Methods of patching deck slabs of reinforced concrete piers are shown in figures 11-20 and 11-21. Slabs may be broken through by overloading. If this is a relatively small area and near the center of a span, it can be repaired by cutting out the deck and reconcreting, as shown in figure 11-20. To repair a hole, concrete may be beveled, as shown in figure 11-20; or, in addition to beveling, the area to be removed may first be scored along the breakline, using a saw, to a depth of 1-1/2 inches. The depth is to be adjusted where reinforcing is encountered. No joint in the slab should be made adjacent to, or at the edge of a supporting beam nor at or near the ends of reinforcing bars. If it is necessary to cut the slab



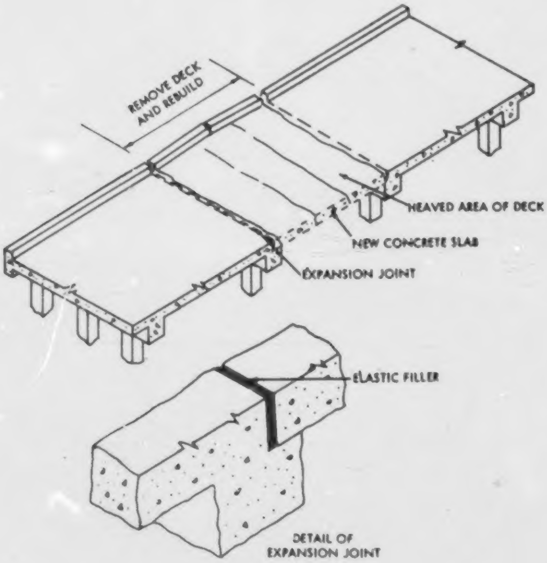
117.269
Figure 11-19. —Cracked and spalled beams.


ALTERNATE METHOD OF CUTTING SEAT
BROKEN AREA OF SLAB ADJACENT TO SUPPORT CUT OUT FOR RE-CONCRETING
PILE CAP
SEAT FOR NEW PART OF CONCRETE SLAB
CONCRETE DECK

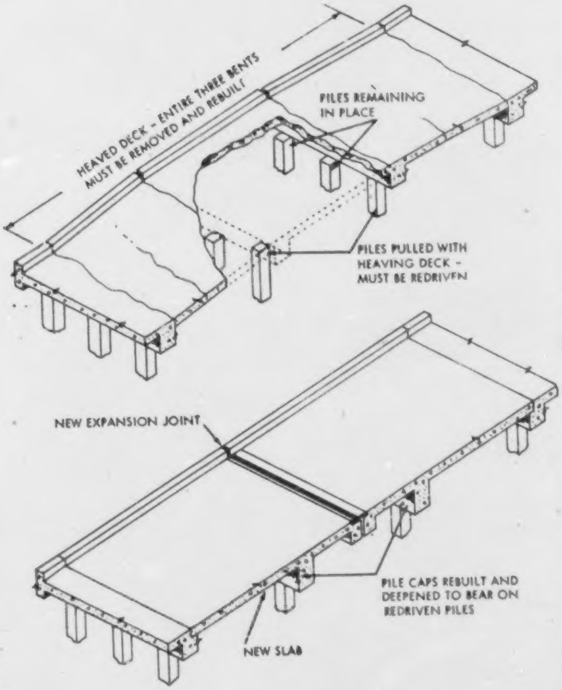
117.271
Figure 11-21. —Repair to damaged edge of slab.

back to the supporting beams, or replace the slab, a seat should be cut into the beam to the depth of the slab and one-quarter to one-third the width of the beam (See fig. 11-21.) If deck slabs have been damaged by heaving, they must be replaced. Make provisions for adequate expansion joint in the new slab. (See fig. 11-22.) If two or more adjacent slabs have heaved, it will often be found that piles have been pulled up with the slabs. When this condition occurs, the piles should be redriven to a firm bearing and necessary repairs made to concrete caps. (See fig. 11-23.)

EXPANSION JOINTS.–Where expansion joints have proven inadequate in number or are not functioning properly, heaving will result. Where joints are too far apart, cut additional joints with a concrete saw and fill with an approved type joint sealer. Asphalt, tar, and certain other materials may be used with satisfactory results for sealing joints. Sealing material should adhere to the concrete and should remain plastic at all temperatures. It should not become hard and brittle in low temperatures or become so soft that it flows from the joint during intense heat or so tacky that it is picked up by vehicle tires.


REMOVE DECK AND REBUILD
HEAVED AREA OF DECK
NEW CONCRETE SLAB
EXPANSION JOINT
ELASTIC FILLER
DETAIL OF EXPANSION JOINT

117.272
Figure 11-22. –Heaving of concrete deck.


HEAVED DECK - ENTIRE THREE BENTS MUST BE REMOVED AND REBUILT
PILES REMAINING IN PLACE
PILES PULLED WITH HEAVING DECK - MUST BE REDRIVEN
NEW EXPANSION JOINT
PILE CAPS REBUILT AND DEEPENED TO BEAR ON REDRIVEN PILES
NEW SLAB

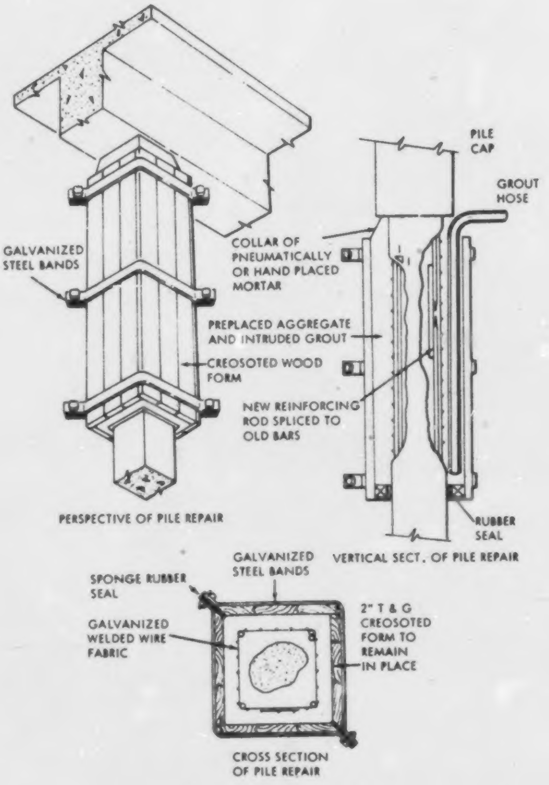
117.273
Figure 11-23. –Piles pulled by heaving deck.

RESURFACING.–Portland cement concrete pier decks that have widespread surface deterioration may be restored by resurfacing with asphalt. The existing slab must be properly prepared prior to placement of new asphalt surface course. Clean all loose, scaled, and foreign matter down to sound concrete, using power wire brooms and compressed air. Flush with high-pressure fresh water to remove salt, if near sea water. All cracks must be cut to a clean rectangular trench, usually not less than 1/2-inch wide by 1-1/2-inches deep (adjust depth to suit reinforcing steel). Fill trench to within 1/2 inch of the top with a high softening point asphalt mastic or joint-filling compound. Paint the surface of the concrete for three to four inches on both sides of the trench with asphalt emulsion and cover with 30-pound asphalt-impregnated felt 4 inches wider than the trench.

It is very important to seal the cracks properly to eliminate reflection cracking and subsequent premature failure of the new asphalt surface cover. Liquid asphalt is applied to the surface of the Portland cement surface as a primer, and a dense graded mix of asphalt concrete or sheet asphalt is laid as a surface in accordance with a predetermined design. To protect concrete from chemical deterioration, a practical remedy is to apply a layer of dense impervious concrete properly anchored to the old work or some of the newer materials, such as epoxy resin formulations.

Substructure Repair

Free standing components of structures damaged or deteriorated by such means as spalling or longitudinal or horizontal cracks in piles and bracing can be repaired above the water-line. Pressure-applied mortar, epoxy formulations, normal Portland cement concrete, or grout are applicable materials. Encasement of damaged portions in reinforced concrete is the conventional method of repairing piling. It is always preferable to place concrete in air if economical and feasible; however, this requires the use of cofferdams, and it is not always an economical solution. When the solution dictates, concrete can be placed under water. Forms may be used as shown in figures 11-24 and 11-25. Additional reinforcing in the form of rods or mesh is placed around the damaged pile, and sectional forms are used to hold the concrete in place until it cures. Forms may be made of pipe, sheet metal, or wood and are split in half vertically so that they can be placed around the pile and bolted together above the water. Each section is then slid into place and new sections added until the desired length is obtained. The form is then filled with concrete. Forms may be left in place or removed for reuse. Where only a section of the pile is to be encased in concrete and the forms do not extend to the mud line, the lowest section of the forms must be closed to hold the concrete or aggregate and grout in place. (See fig. 11-24.) Pressure-applied concrete may be used to make sectional forms. These are built upon cylinders of expanded metal laths shaped to fit around the pile. Wire mesh reinforcement may be used outside of the metal lath where additional strength is required. Pressure-applied concrete is used to make a sectional form one or two inches thick, and the concrete is allowed to set. This form is then dropped into place and filled with concrete.

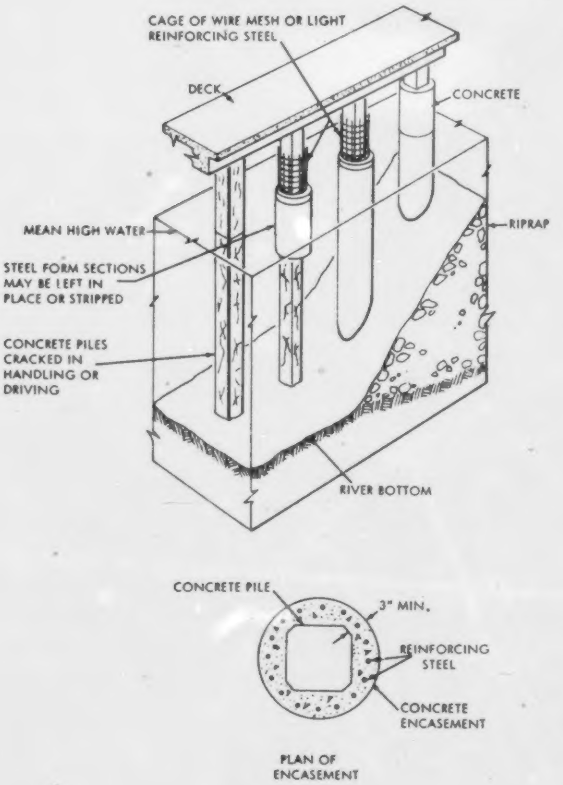

PILE CAP
GROUT HOSE
GALVANIZED STEEL BANDS
COLLAR OF PNEUMATICALLY OR HAND PLACED MORTAR
PREPLACED AGGREGATE AND INTRUDED GROUT
CREOSOTED WOOD FORM
NEW REINFORCING ROD SPLICED TO OLD BARS
PERSPECTIVE OF PILE REPAIR
RUBBER SEAL
GALVANIZED STEEL BANDS
VERTICAL SECT. OF PILE REPAIR
SPONGE RUBBER SEAL
GALVANIZED WELDED WIRE FABRIC
2" T & G CREOSOTED FORM TO REMAIN IN PLACE
CROSS SECTION OF PILE REPAIR

117.274

Figure 11-24. —Encasement of damaged piles (wood form).

METAL

Inspections of corroded, weakened, or damaged areas are essential for determining the best methods or needs for repair coating or replacement of steel members in the various structures. Main members are normally replaced when 30 percent or more of the section has been removed by corrosion or when seriously deformed. In the planning of replacements, consideration must be given to the rate of corrosion or actual decrease


CAGE OF WIRE MESH OR LIGHT REINFORCING STEEL
DECK
CONCRETE
MEAN HIGH WATER
RIPRAP
STEEL FORM SECTIONS MAY BE LEFT IN PLACE OR STRIPPED
CONCRETE PILES CRACKED IN HANDLING OR DRIVING
RIVER BOTTOM
CONCRETE PILE
3" MIN.
REINFORCING STEEL
CONCRETE ENCASEMENT
PLAN OF ENCASEMENT

117.275

Figure 11-25. —Encasement of damaged piles (metal form).

in section. If adjacent members show signs of serious deterioration, it may be best to replace whole frames or bents. Never remove a stressed member until the stress has been relieved by temporary bracing, shoring, or jacking, because, if the stress is not removed, the member may spring out of place when loosened, making it very difficult to replace the member. In the replacement of piles, the load should be shifted temporarily to adjacent piles by means of temporary beams or jacks. The replacement of wales on bulkheads may require the excavation of the fill to relieve the lateral loads. The structures must retain their structural stability at all times. In most cases the maintenance and repair of metal structures will be handled by the Steelworkers. At times, though, the Builder may be working with the Steelworker in these operations, so let us consider some of the common methods of maintenance and repair

Maintenance Methods

New members must be accurately fabricated to match the old work. Special care must be taken to be sure that all bolt and rivet holes line up with original members. Prior to the placement of the new member, all old rivets or bolts must be removed in the most expeditious manner by using hand or pneumatic chisels, saws, wrenches, or by burning them off before removing the old member. Place the new member in position and line up all holes by adjusting jacks or bracing as necessary. Place a few bolts to hold the member, then fasten securely in place by riveting, placing additional bolts, or welding.

In the replacement of bearing piles, the new pile is generally driven alongside the old one at a slight angle. It is then cut off at the proper elevation, capped, usually by welding on a steel plate, and pulled into position by block and tackle. If the old pile is pulled and a new one driven, care must be taken to transfer the load temporarily until the new pile can assume the load. Care must be taken to bore or punch the bolt holes in the cap to conform with the holes in the floor beam or stringer.

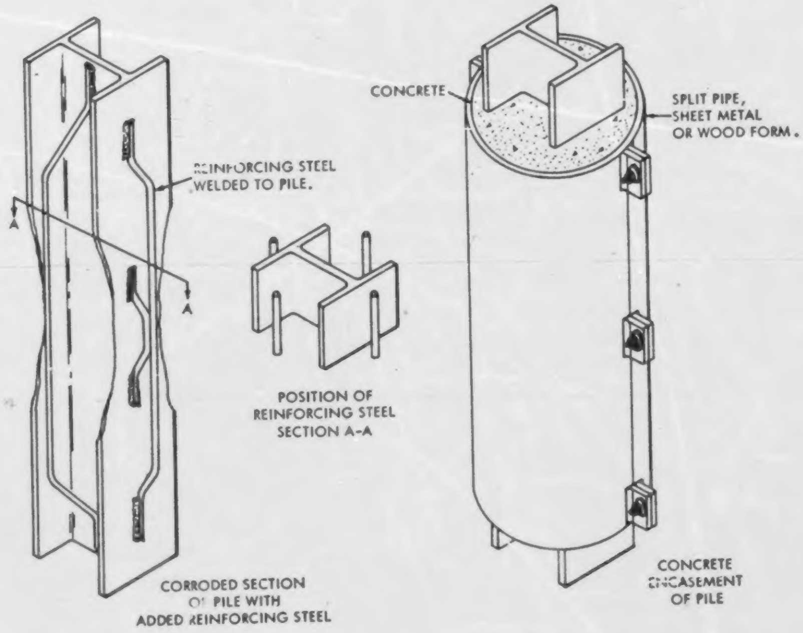
Precautions may be necessary when replacing wales and sheet metal bulkheads because they often retain materials that have a low angle of repose. The old wales are left in place or at least until new wales are installed just above or below the originals. Occasionally they can be connected to existing tie rods; however, in most cases, new tie rods and deadmen should be installed.

Badly deteriorated sheet pile is generally protected by new sheet piling being driven outside the old piling and provided with new wales, rods, and deadmen. The space between the piles must be filled with well-tamped earth, sand, gravel, or concrete, depending upon conditions at the site.

Steel members that have corroded in only limited areas may be repaired by welding fish plates onto the flanges and web. The corroded area should be first thoroughly cleaned and feather edges burned off back to a point where the metal is of sufficient thickness to hold a weld. Fish plates should be of sufficient cross sectional area to develop the full strength of the original section and should extend beyond the top and bottom of the corroded zone. Another method is to encase the corroded section in reinforced concrete. After cleaning the corroded area and cutting back the corroded edges, weld the reinforcing rods to the flanges and web. A form is then placed around the corroded section and filled with concrete. Figure 11-26 illustrates this procedure for steel H-pile. The same system can be used for other structural members.

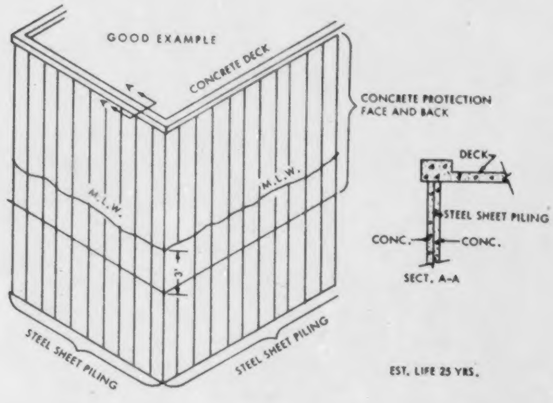
Sheet Piling Repair

Sheet piling usually serves as a bulkhead to retain earth or other fill. Holes in the bulkhead will result in loss of materials and settlement behind the bulkhead. Local damage or holes can be repaired by welding on plates, or sections of steel sheet piling. If the holes are small, wooden plugs can be used to fill the holes. Usually, it is necessary to install new sheet piling in the deteriorated areas; however, it may be economically feasible to protect the damaged sheet piling with a concrete facing, as shown in figure 11-27. Remove all rust, scale, and marine growth before placing concrete. Concrete cover, when applied to the exposed exterior face of the piling, should be at least 6 inches in thickness and extend well beyond the area of corrosion, damage, or deterioration. Form work should be of wood, supported in place by stud bolts that are welded to the sheet piling. Use heavy zinc-coated bolts and nuts. It is preferable that the wood forms be left in place, because they will provide protection against damage from floating debris and erosion for some time. Where the back of the bulkhead can be easily exposed, it may be advisable to completely encase the sheet piling in concrete. Minimum thickness of concrete facing where the piling is completely encased in concrete should be 3 inches. Care must be taken in replacing backfill when sheet pile has been encased. GRANULAR materials


REINFORCING STEEL WELDED TO PILE.
A
A
POSITION OF REINFORCING STEEL SECTION A-A
CORRODED SECTION OF PILE WITH ADDED REINFORCING STEEL
CONCRETE
SPLIT PIPE, SHEET METAL OR WOOD FORM.
CONCRETE ENCASEMENT OF PILE

117.276

Figure 11-26. —Concrete encasement of steel pile.


GOOD EXAMPLE
CONCRETE DECK
CONCRETE PROTECTION FACE AND BACK
M.L.W.
M.L.W.
3'
STEEL SHEET PILING
STEEL SHEET PILING
DECK
STEEL SHEET PILING
CONC.
CONC.
SECT. A–A
EST. LIFE 25 YRS.

117.277

Figure 11-27. —Concrete encasement of steel sheet pile.

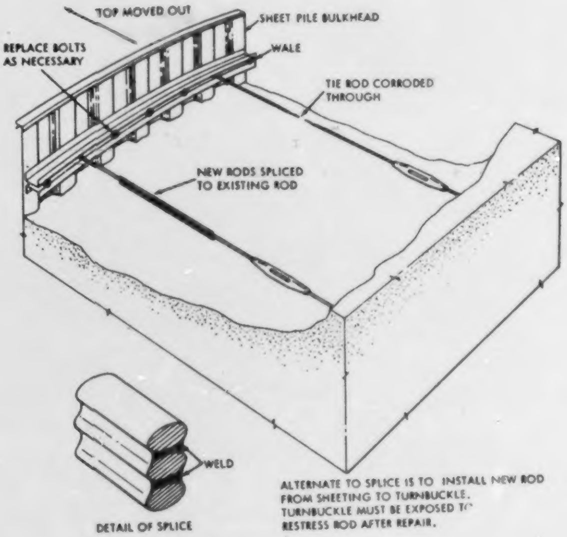
are preferable. Fill should be placed in layers and well compacted.

Tie Rod Repair

Deteriorated tie rods will allow the top of a bulkhead to move outward. Remove the fill to expose the tie rods and turnbuckles by starting the excavation at the back face of the bulkhead and progress inshore in as narrow a trench as practical, along the tie rod to the deadmen. Thoroughly clean the tie rods and turnbuckle by removing rust and corrosion. Repairs may be made by welding new rods onto the corroded area (see fig. 11-28) or by installing new rods from the turnbuckle to the face of the wall or outside of the wales. Check the condition of the deadmen and either make necessary repairs or strengthen them, as required. Tie rods should be replaced or repaired, one at a time. Coat new work with bituminous material, wrap with fabric tape, and apply another coating of bituminous material over the tape; and then backfill the trench.

WOOD

Wood pile and timber structures in a marine environment are susceptible to infestation and attack by marine organisms or wood rot spores. Therefore, treated piles and timbers should be used in the repair or replacement of such members in structures unless there is a specific reason for doing otherwise, on the basis of the economic expected life. Southern Yellow Pine, Douglas Fir, and oak have been found to be most suitable for waterfront structures; however, hemlock, larch, spruce, cedar, and tamarack can be used. Figure 11-29 shows an untreated timber destroyed by marine borers in seven months. Bolts, washers, spikes, drift pins, and other hardware used in repair of timber members must be heavily galvanized.

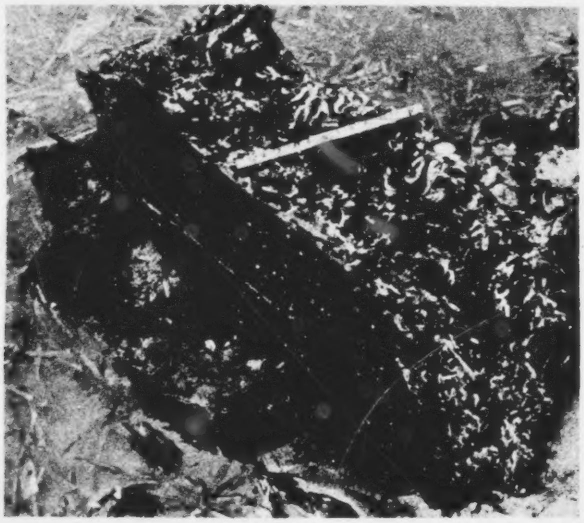

TOP MOVED OUT
SHEET PILE BULKHEAD
REPLACE BOLTS AS NECESSARY
WALE
TIE ROD CORRODED THROUGH
NEW RODS SPLICED TO EXISTING ROD
WELD
DETAIL OF SPLICE
ALTERNATE TO SPLICE IS TO INSTALL NEW ROD FROM SHEETING TO TURNBUCKLE. TURNBUCKLE MUST BE EXPOSED TO RESTRESS ROD AFTER REPAIR.

117.278

Figure 11-28. —Repair of tie rods.

Decking

The use of creosote-treated lumber for wood "decking" is not recommended. Deck surfaces drain rapidly and, being well ventilated, dry rapidly so that the principal concern is not the same as it is for the covered, unaccessible structural framing. Usage and wear from traffic is generally the cause of deck repair and replacement. Top surface decking, over which vehicular and pedestrian traffic passes, should be replaced when the top surface becomes excessively uneven, hazardous, or worn to a point of possible failure of the decking. Replacement should be



117.279

Figure 11-29. —Pile cap destroyed by marine borers.

with edge-grain timber, surfaced on four sides. Decking should be laid with 1/2-inch to 3/8-inch space between each plank to permit ventilation and drainage. The top surface should be reasonably smooth and level, particularly where repaired areas meet existing decking. End joints should be staggered where existing and new decking meet. Decking should be nailed securely at every stringer with 6-inch spikes for 3-inch decking and 7- or 8-inch spikes for 4-inch decking. Spikes should be driven flush with the top deck planking. Care should be taken to rebuild into the repaired decking area openings or access for under-pier fire-fighting nozzles or sprayers and for access to piping, valves, and fittings. Decking for relieving platforms that have an earth-fill should be a double layer of pressure-treated lumber laid without spacing between planks.

Stringers

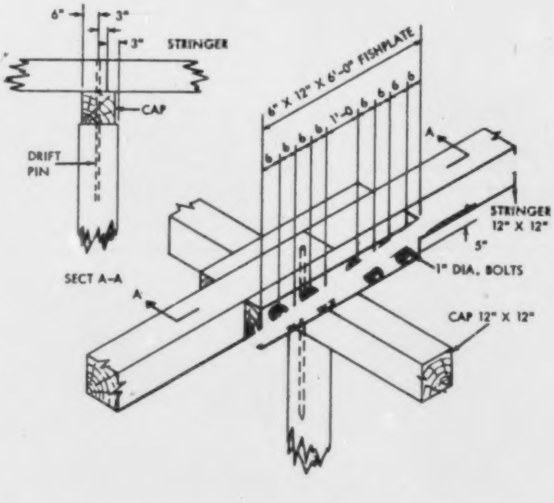
Stringers that have rotted or have been damaged should be replaced. Replacement stringers should be tightly bolted where they lap with existing stringers that are to remain, and they should be pinned or bolted down to caps. Stringers that extend continuously for the length of the pier may be replaced in part by splicing to sound parts of the timber. Splices should be placed directly over pile caps, and the splices in adjacent stringers should be staggered where possible. A typical splice for a 12-inch by 12-inch stringer or cap is shown in figure 11-30.

Pile Caps

Pile caps that require replacement because of rot or damage should be completely replaced between the splices of the original structure. Bolt holes in new caps should be carefully made to align properly with bolt holes in existing caps. It is preferable to use new fish plates, particularly if they are of timber. A typical splice is shown in figure 11-30.

Braces

Diagonal and sash braces that have rotted, have been broken, or have been weakened by marine borer attack should be replaced. Each brace should be replaced completely rather than spliced. Bolt holes should be carefully placed for proper alignment. When wood braces are fastened to piling, the pile should not be cut to



117.280

Figure 11-30. —Stringer splice.

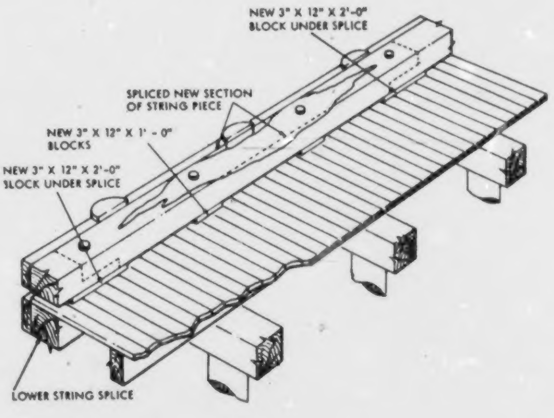
obtain a flush fit. The braces should be bolted, if possible, above the high waterline. After drilling, bolt holes should be treated with preservative, preferably with a specially designed bolt hole treated that forces the preservative into the hole under pressure. Where decking has been removed for repairs, it is often possible to drive brace piles to provide lateral stiffness. This eliminates all bolt holes except at the top of the structure immediately under the decking.

Fire Curtain Walls

Fire curtain walls that have rotted or that have been damaged or severely attacked by marine borers should be restored to the original condition. When damaged timbers are replaced they may be spliced out. Splices should not be made in the same location on both sides of the wall because an open crack would remain. The curtain wall should be as airtight as possible after repairs are completed. Wood fire curtains are usually made of two layers of timber, the joints in one layer running diagonally to the joints in the other. It is important that the joints be tight and that both sides of the wall be completely repaired.

String Pieces

The string piece is sometimes referred to as the curb, bullrail, or backing log. Because of its exposed position, it is subject to much wear and, in addition, to constant wetting and drying. It is bolted to the caps and lower string piece. The string piece may be repaired by splicing in new material as needed. The length of the replaced sections should be not less than two complete bents. The string piece should be set on blocks between two and three inches thick and between three and four feet on centers to permit drainage under the string piece. New blocks should be placed under any part of the string piece that is replaced. If it is necessary to replace any part of the lower string piece, it should be replaced for the full length of the timber as originally built. (See fig. 11-31.)



117.281

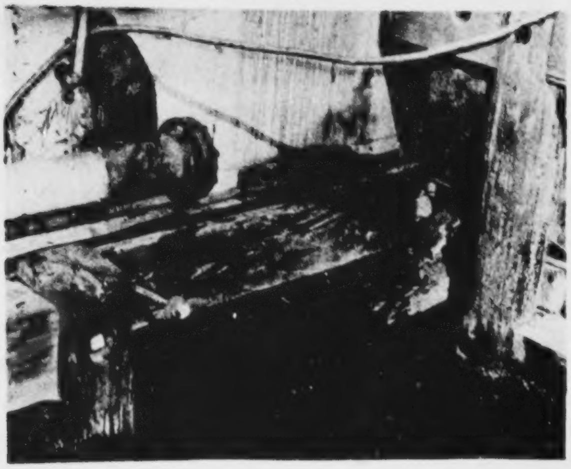
Figure 11-31. —Repair of string piece.

Chocks

Chocks between piles that are rotted or broken, as shown in figure 11-32, should be replaced. The new timber chock should be tightly fitted in place and bolted to one string piece. (See fig. 11-33.)

Wood Piles

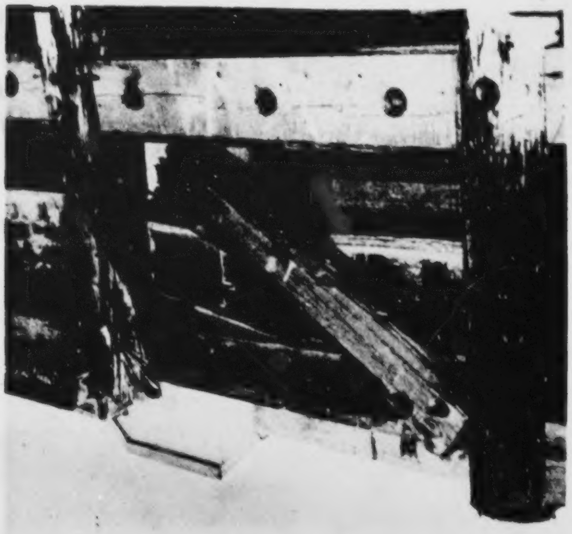
The decayed top of woodbearing piles can be repaired by cutting off the damaged portion and building up to the proper height with sound timber. (See fig. 11-34.) Drift pins should be driven through the cap and down through the new section of pile. This involves the removal of some of the deck planking. In every case, fish plates of metal or treated wood should be used to hold the new section in place. Fasten fish plates securely with spikes, lag screws, or bolts. Where all the piles in a bent have decayed tops, but there is less than a foot of unsound piling, the method shown in figure 11-35 may be used. The top of each pile in the bent is cut off to allow the installation of an additional 12-inch x 12-inch cap under the existing cap. Drive drift pins through caps into the piles to hold the tops in place. In most cases, the connection of caps to piles should be further strengthened by bolting them together with 1-inch bolts and 2-1/2-inch x 3/8-inch steel straps. Use 1-inch bolts for bolting the two caps together.



117.282

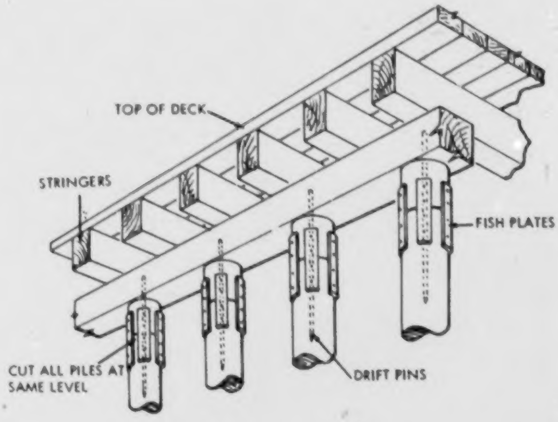
Figure 11-32. —Decayed chock.

Piles that are broken or badly damaged should be replaced. (See fig. 11-36.) The old pile should be pulled and a new one driven in its place. Where old piles cannot be pulled or where they break off, the old pile must be cut off as far down as possible and a new pile driven alongside of it. After driving, the head of the new pile is pulled into place and fastened to the cap with a drift pin, or by the use of fish plates. (See fig. 11-37.) Treated replacement piles should be used for all structural pier piles; however, on major operations and supply piers, where the life expectancy of the fender system is relatively short because of its continuous exposure to the berthing of major ships, the use of untreated,



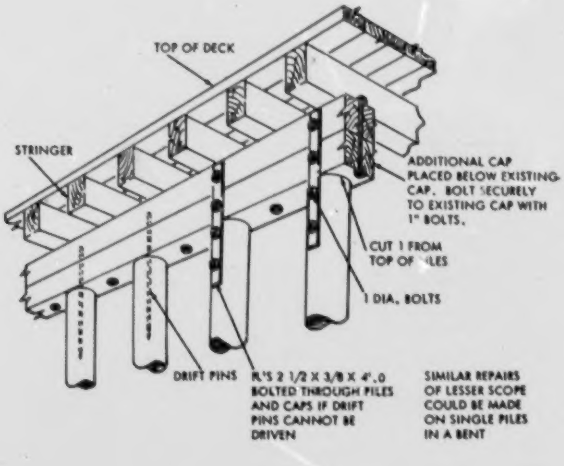
117.283

Figure 11-33. —Chocks between fender piles.


TOP OF DECK
STRINGERS
FISH PLATES
CUT ALL PILES AT SAME LEVEL
DRIFT PINS

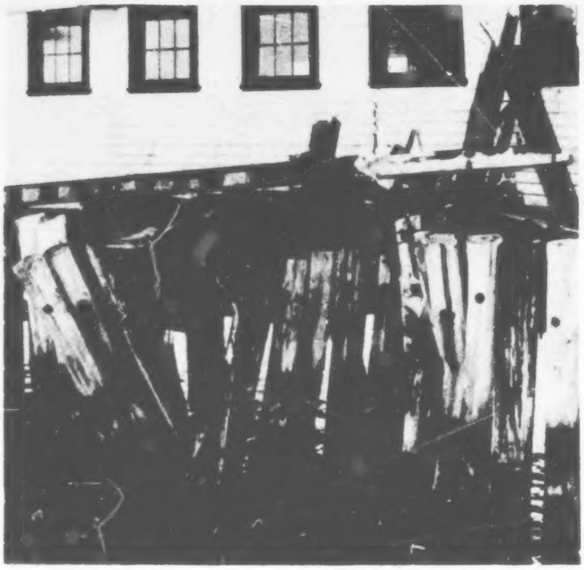
117.284

Figure 11-34. —Replacing tops of piles.


TOP OF DECK
STRINGER
ADDITIONAL CAP PLACED BELOW EXISTING CAP. BOLT SECURELY TO EXISTING CAP WITH 1" BOLTS.
CUT 1 FROM TOP OF PILES
1 DIA. BOLTS
DRIFT PINS
R'S 2 1/2 X 3/8 X 4'.0 BOLTED THROUGH PILES AND CAPS IF DRIFT PINS CANNOT BE DRIVEN
SIMILAR REPAIRS OF LESSER SCOPE COULD BE MADE ON SINGLE PILES IN A BENT

117.285

Figure 11-35. —Repair of top of piles.



117.286

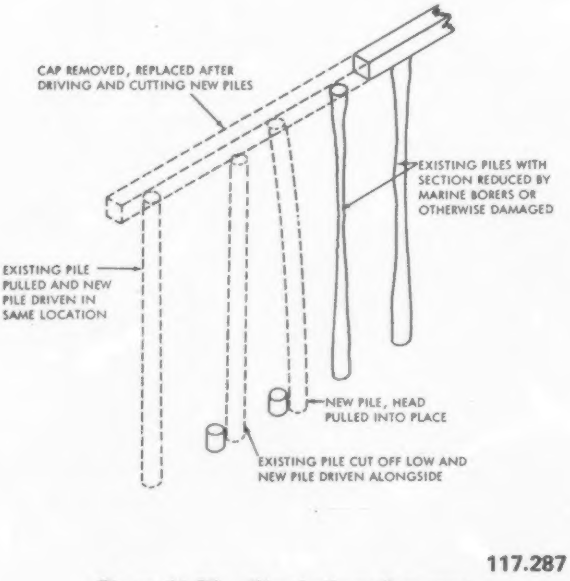
Figure 11-36. –Broken wooden piles.

unskinned piles may be considered structurally suitable and economically sound

Piles that have been weakened by marine borers can be strengthened and protected by encasing them in concrete jackets. Steel reinforcing can be used in the concrete jacket either in the form of bars or wire mesh. Concrete encasement may be used to cover a short section of the pile, where damage is limited, as shown in figure 11-38, or may be extended well below the waterline as shown in figure 11-39. The damaged surface of the pile must be scraped to sound wood. Either metal or wood forms may be used. If wood forms are used, a 2-inch creosoted tongue and groove material should be used and left in place. Fender piles that are broken between the top and bottom wales, as illustrated in figure 11-40, can be repaired by cutting off the pile just below the break, then installing a new section of pile and fitting. Place and bolt a pile section or timber section directly behind the fender pile from top to bottom wales. A metal wearing strip should be spiked to the wearing edge of the pile.

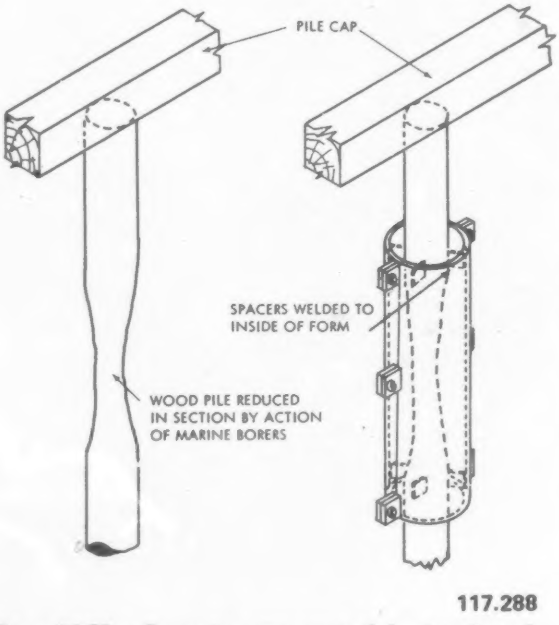
Sheeting

Piers and quay walls may have a bulkhead of wood sheet pile to retain the fill on the shore


CAP REMOVED, REPLACED AFTER DRIVING AND CUTTING NEW PILES
EXISTING PILES WITH SECTION REDUCED BY MARINE BORERS OR OTHERWISE DAMAGED
EXISTING PILE PULLED AND NEW PILE DRIVEN IN SAME LOCATION
NEW PILE, HEAD PULLED INTO PLACE
EXISTING PILE CUT OFF LOW AND NEW PILE DRIVEN ALONGSIDE

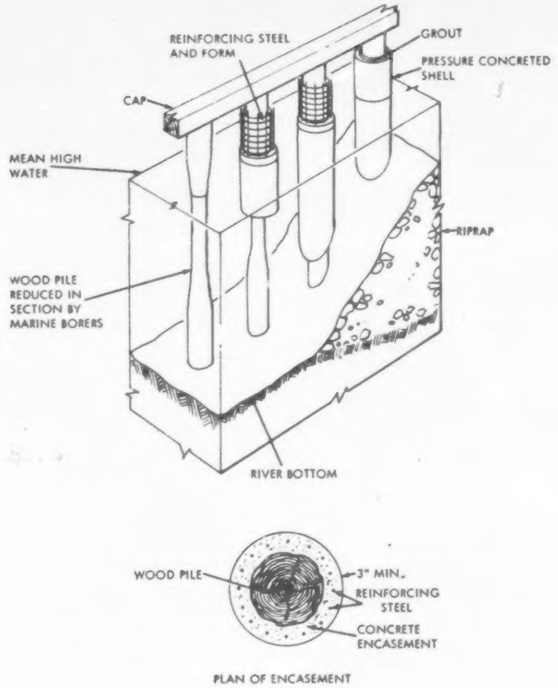
117.287

Figure 11-37. –Wood pile replacement.


PILE CAP
SPACERS WELDED TO INSIDE OF FORM
WOOD PILE REDUCED IN SECTION BY ACTION OF MARINE BORERS

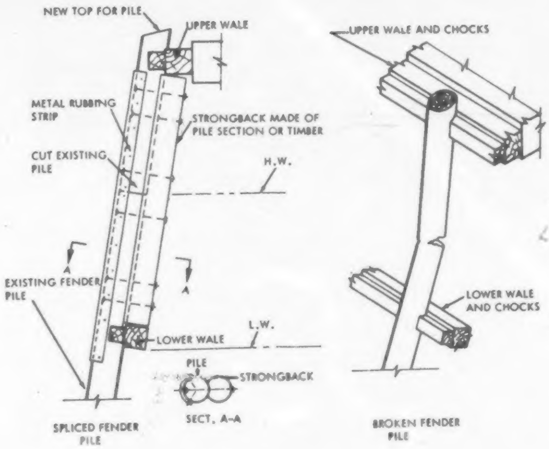
117.288

Figure 11-38. –Concrete encasement of short section of wood pile.


REINFORCING STEEL AND FORM
GROUT
PRESSURE CONCRETED SHELL
CAP
MEAN HIGH WATER
RIPRAP
WOOD PILE REDUCED IN SECTION BY MARINE BORERS
RIVER BOTTOM
WOOD PILE
3" MIN.
REINFORCING STEEL
CONCRETE ENCASEMENT
PLAN OF ENCASEMENT

117.289

Figure 11-39. —Extensive concrete encasement of wood pile.


NEW TOP FOR PILE
UPPER WALE
UPPER WALE AND CHOCKS
METAL RUBBING STRIP
STRONGBACK MADE OF PILE SECTION OR TIMBER
CUT EXISTING PILE
H.W.
A
EXISTING FENDER PILE
A
LOWER WALE AND CHOCKS
L.W.
LOWER WALE
PILE
STRONGBACK
SECT. A–A
SPLICED FENDER PILE
BROKEN FENDER PILE

117.290

Figure 11-40. —Fender pile repair.

side. Riprap is usually placed at the foot of the sheeting for strengthening. Extensive deterioration of the bulkhead will result in loss of fill and settlement above the affected area. Repairs usually require the driving of sheet piling to form a new bulkhead a minimum of one foot inside the old one, so as to avoid the driving frames or wales attached to the old bulkhead. New sheet piling may be pressure-treated wood, concrete, or sheet steel. Steel sheet piling is normally used for the new bulkhead, because oftentimes the work must be done inside a pier shed. In this case, steel piling is driven in maximum lengths possible and additional lengths welded on successively. The new sheet pile should extend to a minimum of three feet below the toe of the deteriorated wood sheeting. The fill at the inside edge of the old bulkhead is normally removed before driving the new sheet piling. When this is done, a concrete cap should be placed over the new sheeting to form a seal with the existing construction.

Dolphins

Maintenance of dolphins includes the replacement of fastenings and any wire rope wrapping that has become ineffective through corrosion or wear. If dolphins are connected by a catwalk, maintenance of the catwalk includes the replacement of damaged or deteriorated timbers or the cleaning and painting, or the replacement, of the steel members. Repairs of dolphins include replacement of piles, wire rope wrappings, and blocking. If any piles have to be replaced, the fastenings should be removed only as far as necessary to release the piles that are damaged. Care should be taken to drive the new piles at the proper angle so they will not have to be "pulled" too far to fit them in place. The size of piles to be replaced should be carefully noted, particularly at the head or intermediate point where they are fitted together with the other piles. Much trouble in cutting and fitting the replacement piles can be avoided by selecting piles with the proper size head. All replacement piles should be driven before any are brought together. After all are driven, the center cluster should be brought together first, and should be fitted, chocked, bolted, and pinned; they are then wrapped with wire rope. All cuts in piles for fittings, bolts, and wrappings should be thoroughly field-treated with creosote. Frequently, it is more economical to build a new dolphin rather than to repair an existing one.

STONE, MASONRY, AND EARTH

Some structures, such as breakwaters and seawalls, depend upon their mass for stability against wave action and currents. Materials commonly used for such structures are stone, blocks of concrete, cast-in-place concrete, and earth. Earth structures are usually covered with a protective coating, such as riprap, to hold them in place.

The most common cause of deterioration and damage to mass structures is wave action, particularly during storm conditions. Severe wave action may move stones out of place, when built into a wall, or move others by washing out sections of a breakwater or causeway. This damage makes the structure more susceptible to additional damage. Repairs should be made as soon as possible.

Stone Structures

Stone structures are considered to be those constructed of stone, blocks of concrete, or special concrete shapes, such as tetrahedrons, piled up or distributed in a random fashion. Some structures may have an earth core retained in place by stone composing the area that is exposed to wave action. In repair of the damage, consideration must be given to the cause of damage, such as, an unusually severe storm, need for strengthening of structure, and too steep side slopes. Unless it is evident, after study by design engineers, that changes in design are required, the structural damage should be repaired with materials the same as the original to restore the structure to its original strength, elevation, and cross-section. Depressions washed out of the bottom in the vicinity of structures should be replaced with sand or GRANDULAR materials up to original level before replacing stone, either by dumping from the undamaged part of the structure, or by placing from a barge using a floating derrick.

Masonry Structures

Structures made of cut stone and cast concrete, made in shapes and fitted up tightly together or laid up with mortar or similar material, are considered masonry structures. Units may be bonded together by overlapping, by metal clamps, dowels, bed plugs, or by shapes of the blocks. (See fig. 11-41.) All metal fastenings should be zinc-coated and well bedded in mortar. Sections of masonry that have washed out or have been damaged should be completely rebuilt, bonding the units to each other or using metal fastenings as necessary. Masonry walls that have cracked because of unequal settlement can be rebuilt; adding reinforcing bars as shown in figure 11-42. Repair

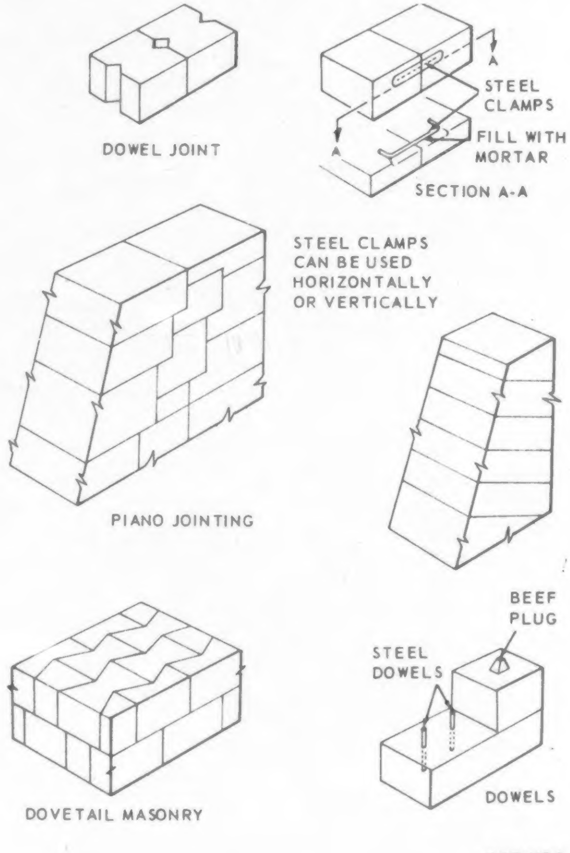


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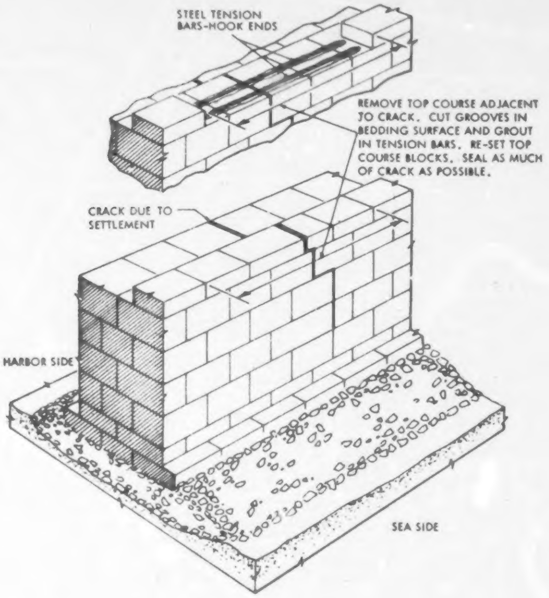
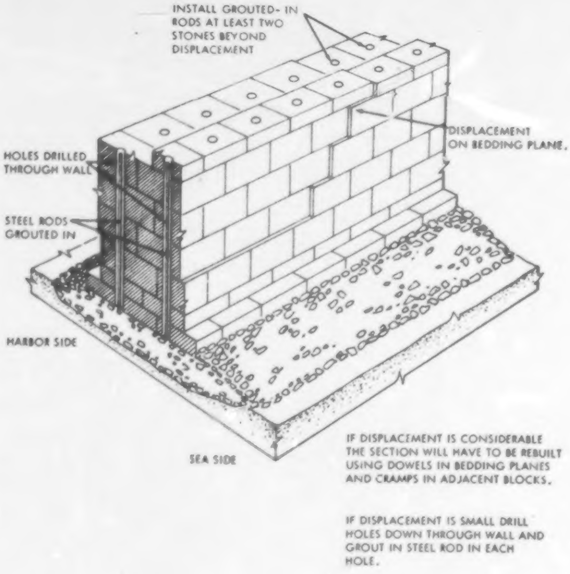
Figure 11-41. —Anchoring masonry blocks.


STEEL TENSION BARS-HOOK ENDS
REMOVE TOP COURSE ADJACENT TO CRACK. CUT GROOVES IN BEDDING SURFACE AND GROUT IN TENSION BARS. RE-SET TOP COURSE BLOCKS. SEAL AS MUCH OF CRACK AS POSSIBLE.
CRACK DUE TO SETTLEMENT
HARBOR SIDE
SEA SIDE

117.292

Figure 11-42. —Repair to cracked masonry walls.


INSTALL GROUTED- IN RODS AT LEAST TWO STONES BEYOND DISPLACEMENT
DISPLACEMENT ON BEDDING PLANE.
HOLES DRILLED THROUGH WALL
STEEL RODS GROUTED IN
HARBOR SIDE
SEA SIDE

IF DISPLACEMENT IS CONSIDERABLE THE SECTION WILL HAVE TO BE REBUILT USING DOWELS IN BEDDING PLANES AND CRAMPS IN ADJACENT BLOCKS.

IF DISPLACEMENT IS SMALL DRILL HOLES DOWN THROUGH WALL AND GROUT IN STEEL ROD IN EACH HOLE.

117.293

Figure 11-43. —Reinforcing vertical walls.

of cracked walls should be delayed until settlement is complete, if possible. Where sections of walls have been displaced by sliding, an investigation should be made to determine the cause before it is rebuilt. If water builds up back of walls, the weep holes should be cleaned and new ones installed to relieve the pressure. Walls that fail because they are inadequate should be redesigned before they are rebuilt. It is advisable to provide clamps for reinforcement where the displacement of a wall is minor. If it is not necessary to rebuild the wall, it can be reinforced by drilling holes down through the wall at the area of displacement and a short distance beyond, inserting steel rods in the holes and filling the holes with cement mortar. (See fig. 11-43).

Earth Structures

The use of earth for waterfront structures is confined largely to dikes and levees. It is also used for the interior of such structures as causeways, moles, and breakwaters; as backfill for quay walls and similar structures; and for fill for caissons and cellular structures. Earth that is exposed to wave action must usually be protected by riprap, cut stones, concrete blocks, or similar materials. The washing away of this protection exposes earth to erosion by rain, waves, and currents. When the earth is eroded, it should be replaced and wall-compacted prior to replacing the protecting material. Where earthfill is supported by a bulkhead, cell, caisson, or similar structure, the supporting structure should be repaired and the fill replaced in layers, with the coarser materials next to the bulkhead and the finer materials inboard. Layers must be compacted and consolidated. All materials for dikes and levees should be impermeable to prevent water from working through the structure. Vegetative covering is usually grown on the sides and top of earth structures to prevent erosion. Areas where vegetation has died or been damaged should be replanted.

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